
Ministry of Road Transport &
Highways

MANUAL FOR CONSTRUCTION AND SUPERVISION OF BITUMINOUS WORKS

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PREFACE

In India, as in most other countries of the World, Black- topped flexible pavements constitute the main bulk of the total road length. Bituminous layers form a significant part of a flexible pavement and constitute a substantial proportion of the total pavement cost. A well-constructed bituminous course ensures the durability and good performance of the road. Though the principles of bituminous work are well enshrined in the Specifications and Codes of Practice, a need has been felt for a Manual, which covers all aspects of construction and supervision of bituminous works. The Ministry of Road Transport and Highways, has taken the initiative to fulfill this long-felt need of the Manual.

This Manual covers all aspects of construction of bituminous pavements. It does not, however, deal with the design of flexible pavements. The Manual embodies the best practices round the World and is in conformity with recently upgraded Section 500 of Ministry of Road Transport and Highways Specifications for Bituminous works.

Keeping in view the practical problems being faced by road engineers, consultants and contractors; a separate Chapter has been devoted to the Road Building Plant and Equipment making it possible, to select the most appropriate type of plant and equipment suited for a specific job.

The Manual also covers aspects, such as, pre-construction investigations, properties and testing of bituminous materials; mixtures and their design; specifications; equipment; construction supervision and quality control. It is not a substitute for Specifications, which already exist, but is intended for guiding practicing engineers in putting the Specifications into practice.

It also includes some newer technologies, like, the 'High performance Base', 'Stone Mastic Asphalt', 'Micro Asphalt Concrete Resurfacing' and 'Synchronous Spreading for surface Dressing' which have been successfully tried out in developed countries, but would require considerable amount of R&D work including pilot studies/ laying of full-scale test tracks before establishing their suitability to Indian conditions.

This Manual, prepared with the intended purpose of serving as a companion volume alongwith Ministry of Road Transport and Highways Specifications, is the result of untiring efforts made by the officers of the Ministry of Road Transport and Highways and the consultants. I would like it express my appreciation of the commendable efforts put in by all concerned.

With more and more emphasis on mechanization of road building and new technologies ushering in road construction the feedback from all the users of this document is welcome for its review and updating in due course.

New Delhi
November, 2001

S. C. SHARMA
Director General (Road Development) & Addl. Secretary

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CHAPTER 1

INTRODUCTION

1.1. General

A road pavement should be designed and constructed to support the loads imposed on it by the wheels of the vehicles moving over it and to transfer these loads safely to the underlying ground. For satisfactory performance of these functions, the pavement should have some or all of the following desirable characteristics :

1. The pavement should be structurally adequate in thickness and composition of the layers to withstand the stresses imposed on it by the wheel loads and to distribute these loads so that a safe level of stresses are imposed on the soil supporting the pavement.
2. The pavement should have a good hard wearing surface so that the tangential stresses imposed by the wheels do not easily abrade it.
3. The pavement should be dust proof.
4. The pavement should have a good riding quality so that the ride in the vehicles is smooth and comfortable and they consume as little energy as possible in overcoming the road friction. Smooth surfaces also cause less wear and tear on vehicles and make possible the attainment of higher average speeds.
5. The pavement should not be slippery, especially when wet; it should prevent skidding.
6. The pavement surface should result in lowering the levels of noise caused by friction with vehicle tyres.
7. The pavement surface should prevent the ingress of water which can cause softening of the subgrade and consequent loss of support.
8. The pavement should be durable and have a long life. The cost of maintaining it periodically should be low.
9. The pavement should be economical to construct.
10. The pavement system should provide good surface and subsurface drainage.
11. The pavement must result in energy conservation.
12. The pavement must not produce any adverse environmental impact.

1.2. Pavement Types

Pavements can be broadly classified as noted hereunder, from the point of view of their structural behaviour:

1. Flexible
2. Rigid
3. Semi-rigid
4. Composite

Flexible pavement has a low flexural strength. The external load is transmitted to the soil with limited lateral distribution. The pavement is composed of a number of layers, the stronger ones occupying the higher levels and the weaker ones the lower levels. The upper layers are generally made up of materials using bitumen as a binder, and the lower layers are of granular materials.

In contrast, a rigid pavement has a high flexural strength. The pavement carries the load due to the beam action of the pavement slab, which is constructed in high strength cement concrete.

A semi-rigid pavement is intermediate between the flexible and the rigid type of pavements. Materials commonly used in this type of pavement are soil-cement, lean concrete and lime-flyash stabilised soil.

A composite pavement is one which has multiple layers, some of them rigid and some of them flexible. A good example is a pavement having a Rolled Cement Concrete base and a bituminous wearing course.

Overlays of bituminous material are often placed on all of the above types of pavement, at some stage in their life, in order to improve their riding quality and/or to strengthen and extend their useful life.

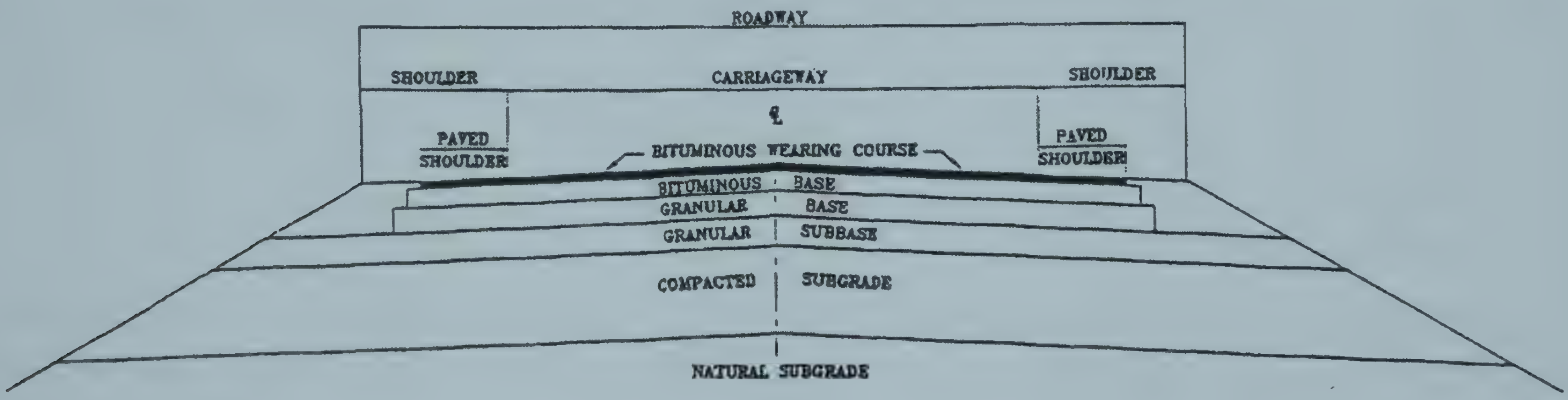
1.3. Flexible Pavement Layers

A flexible pavement consists of a number of layers. A diagrammatic sketch is given in Fig.1.1. The topmost layer in the bituminous surfacing is the wearing course whose purpose is to provide a hard, smooth but skid-resistant, dust-proof and impervious layer. Immediately below comes the bituminous base course or binder course that is designed to withstand the high stresses imposed by the wheel loads. The road base is the heart of the road pavement which absorbs the wheel loads and distributes them to a safe value to the lower layers. The base courses can be of bituminous materials or of granular unbound materials. The bottom-most layers of the pavement crust are known as the sub-base courses. These may be constructed in a variety of materials, such as, gravel, stone aggregates or stabilised soil. The pavement rests on the soil, which is known as the subgrade. Shoulders are adjacent to a road pavement to provide a safe strip for vehicles, which go off the pavement for any reason. They are usually not as substantially constructed as the pavement. In some instances, they are provided with a bituminous surfacing.

1.4. Pavement Drainage

Water falling on top of the pavement should drain away to the sides of the road as a result of the cross-slope or camber provided on the surfacing. For bituminous pavements, common values of cross-slope are in the range of 2 to 2.5 per cent, although a 3.0 per cent minimum cross-slope may be desirable in areas of high intensity rainfall.

Any water which finds its way to the lower layers of the pavement needs to be drained away quickly. This is accomplished by providing a sub-base-cum-drainage layer as part of the pavement, extending to the full width of the roadway (Fig.1.1). It is, however, of vital importance to appreciate that the term "drainage layer", when applied to sub-base material is that the layer is simply more permeable than adjacent pavement layers. On no account should the sub-base layer be regarded as part of a positive road drainage system. The deliberate introduction of surface water run-off into the sub-base layer will rapidly lead to pavement failure.



Note: Granular Sub-base should extend to entire width, only in case or subgrade of low permeability.

Fig. 1.1. Components of a Typical Flexible Pavement

CHAPTER 2

TYPES OF BITUMINOUS BINDERS AND THEIR EVALUATION

2.1. Petroleum Bitumen as a Binder

2.1.1. Manufacture of petroleum bitumen : Bitumen is the thick viscous residue obtained from petroleum distillation. With the advent of the motor vehicle era in the early 1900's, this residue from the oil refineries found a ready use in building smooth, dust-free and water-proof roads. It is now one of the most popular binders used in road construction.

2.1.2. Some common terms : The terms "bitumen" and "asphalt" are often inter-mixed, and different countries attach different meanings to these terms. American terminology uses the name "asphalt" for substances known by the name "bitumen" in British terminology. India generally follows the British practice.

Bitumen, in Indian terminology, is defined as a viscous liquid or a solid, consisting essentially of hydrocarbons and their derivatives, and which is soluble in carbon trichloroethylene and is substantially non-volatile and softens gradually when heated. It is black or brown in colour and possesses waterproofing and adhesive properties. It is obtained by refinery processes from petroleum; it is also found as a natural deposit or as a component of naturally occurring asphalt, in which it is associated with mineral matter.

In American terminology, "asphalt" is the residue obtained from distillation of petroleum crude. The petroleum asphalt used for road construction is usually called "paving asphalt", "asphaltic cement" or "asphalt cement". This should not be confused with "asphaltic concrete", an aggregate-binder mixture which is laid on the road, often referred to in Britain as simply "Asphalt".

A "straight-run bitumen" is a petroleum bitumen of which the viscosity or composition has not been adjusted by blending or by softening with fluxing or cut-back oil or by any other treatment.

A "penetration grade bitumen" is one whose degree of hardness can be measured by a standardised penetration test.

A "blown bitumen" is one obtained by further treatment of straight-run bitumen by running it, while hot, into a vertical column and blowing air through it. In this process, bitumen undergoes a chemical change as a result of which its temperature susceptibility is reduced, having a higher softening point than bitumen of the same penetration, and greater resistance to flow.

2.1.3. General properties of petroleum bitumen : Bitumen has the following general properties :

1. It displays thermo-plastic properties, i.e., it becomes softer when heated and harder when cooled. The way its consistency changes with temperature is termed as its 'temperature susceptibility'.
2. It is viscoelastic in nature. The mechanical properties, although complex can be defined in terms which are analogous to the, elastic modulus of solid materials. This is of particular relevance to polymer modified binders which can only be adequately classified by their mechanical properties; this is considered further in para 2.2.4.
3. It has no specific melting point, boiling point or freezing point, though a form of softening point (Ring and Ball method) is used in its characterisation.
4. It is composed predominantly of hydro-carbons, with small quantities of sulphur, oxygen, nitrogen and metals.
5. It is highly soluble in trichloroethylene, the portion insoluble being generally less than 1.0 per cent.

6. It is colloidal in nature.
7. It is insoluble in water.
8. It is highly impermeable to the passage of water.
9. It is generally hydro-phobic (water-repellent), but may be made hydro-phillic (water-compatible) by the addition of small quantity of surface - active agents.
10. It is chemically inert.
11. It oxidises slowly.

2.1.4. Desirable properties of petroleum bitumen for use in road pavements : For satisfactory performance in a road pavement, bitumen should have the following properties :

1. The bitumen should be fluid enough at the time of mixing to coat all surfaces of aggregates evenly with a thin film. Fluidity is achieved either by heating or by cutting back with a thin flux or by emulsifying the bitumen.
2. The bitumen should be ductile and not brittle.
3. It should have low temperature susceptibility, or in other words, it should exhibit little change in viscosity with changes in temperature.
4. The bitumen should contain an adequate amount of volatiles, and it should not lose them excessively when subjected to higher temperatures. This will ensure its durability over a long period.
5. The bitumen should have a good affinity for the aggregates with which it is in contact and should not strip off in the continued presence of water.
6. The bitumen should be capable of being heated to a suitable temperature for mixing with aggregates without presenting any undue fire hazard.

2.1.5. Laboratory evaluation of straight-run bitumen

Suitability of straight-run bitumen : For determining the suitability of straight-run bituminous binder for road works, the following properties are generally measured:

1. Viscosity as per IS:1206
2. Penetration as per IS:1203
3. Softening Point as per IS:1205
4. Fraass Breaking Point as per IS:9381
5. Temperature Susceptibility.
6. Ductility as per IS:1208
7. Heat Stability as per IS:1209
8. Solubility as per IS:1216
9. Specific Gravity as per IS:1202
10. Loss on heating, thin film oven test, as per IS:1212
11. Retained penetration after thin film oven test as per IS:9382

The requirements of straight-run bitumen used for paving purposes are given in Table 2.1 as per IS:73 "Paving Bitumen-Specification".

Table 2.1. Requirements for Paving Bitumen Type 1 (IS:73-1992)*

Sl. No.	Characteristics	Requirements for Grades						Methods of Test, Ref. to
		S-35	S-45	S-55	S-65	S-90	S-200	
i.	Specific gravity at 27°C, Min	0.99	0.99	0.99	0.99	0.99	0.99	IS:1202-1978
ii.	Water, per cent by mass, Max	0.2	0.2	0.2	0.2	0.2	0.2	IS:1211-1978
iii.	Flash point, Cleveland open cup, °C, Min	175	175	175	175	175	175	IS:1209-1978
iv.	Softening point °C	55-65	50-60	50-60	45-55	40-55	30-45	IS:1205-1978
v.	Penetration at 25°C, 100g, 5 Sec., 1/10 mm	30-40	40-50	50-60	60-70	80-100	175-225	IS:1203-1978
vi.	Penetration ratio[1], Min	35	35	35	35	35	35	--
vii.	Ductility at 27 °C, cm, Min	50	75	75	75	75	-	IS:1208-1978
viii.	Paraffin wax content, per cent by mass, Max	4.5	4.5	4.5	4.5	4.5	4.5	IS:10512-1983 DIN:52015-1980
ix.	Frass breaking point, °C, Min	-4	-4	-6	-6	-8	-10	IS:9381-1979
x.	Loss on heating, thin film oven test, per cent by mass, Max	1	1	1	1	1	2	IS:1212-1978
xi.	Retained penetration after thin film oven test, 25 °C, 100g, 5 Sec, 1/10mm, per cent of original, Min	55	55	52	52	47	42	IS:9382-1979
xii.	Matter soluble in trichlo-roethylene, per cent by mass, Min	99	99	99	99	99	99	IS:1216-1978
xiii.	Viscosity at :							
	a) 60°C, Poises	5000±1000	4000±800	3000±600	2000±400	1000±200	250±50	IS:1206 (Part 2)-1978
	b) 135°C, cst, Min	500	400	350	300	250	125	IS:1206 (Part 3)-1978

$$\text{Penetration ratio} = \frac{\text{Penetration at } 4^\circ\text{C, 200g, 60s}}{\text{Penetration at } 25^\circ\text{, 100g, 5s}} \times 100$$

---

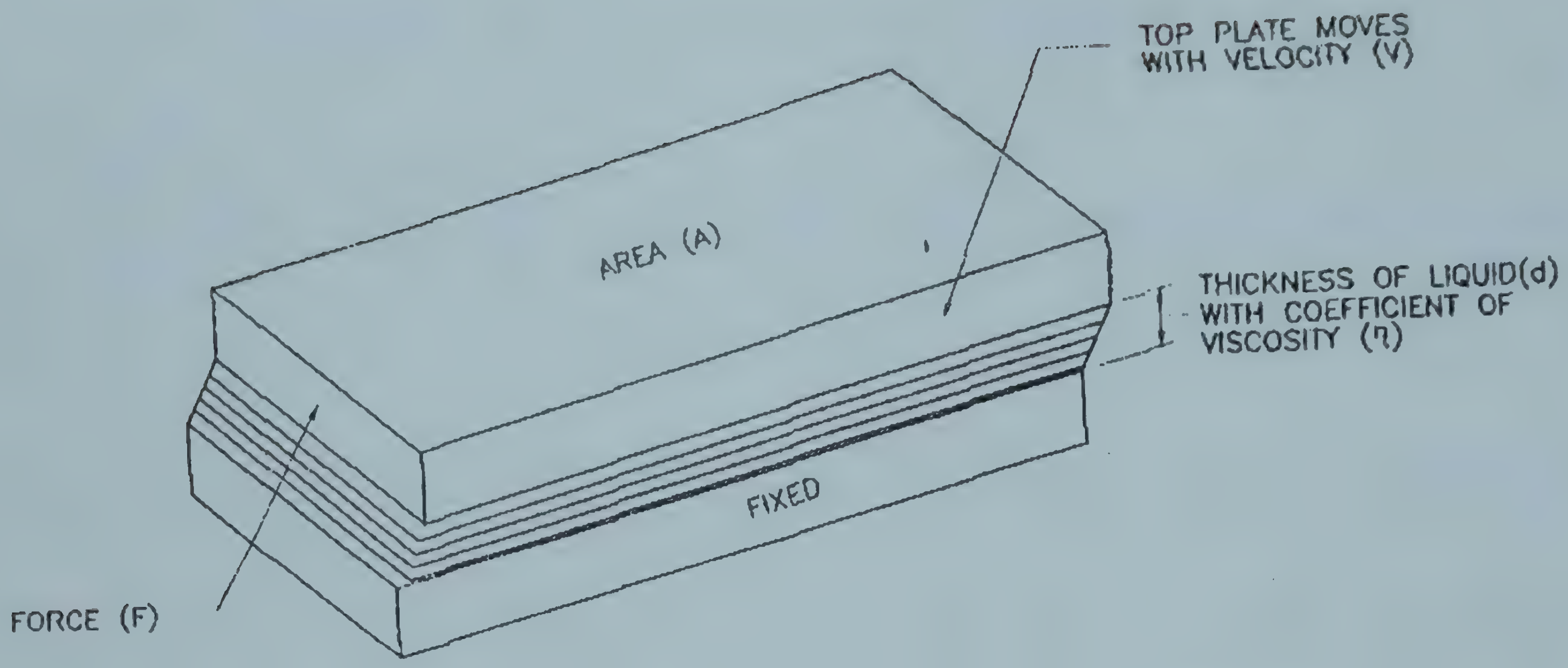
*Appropriate changes as per Draft Amendment No. 2 of 15.09.2000 to IS:73-1992 have been incorporated in this Table.

It may be pointed out here that the paving bitumen referred to as Type 2 in IS:73-1992 is not considered suitable, because of its high wax content and low ductility value. Thus the grades A35, A55, A65 and A90 as given in Table 2 of IS:73-1992 should not be used for paving purposes. Even for paving bitumen of Type 1, the requirements in respect of the Softening Point particularly for the commonly used grades of S-65 and S-90 need to be reviewed in view of bituminous pavement temperatures exceeding 40°C in some parts of the country.

2.1.5.1. Viscosity test : Viscosity is the property which determines the resistance offered by a fluid to a shearing force under laminar flow conditions. It is the opposite of fluidity.

The coefficient of dynamic or absolute viscosity (symbol η) is the tangential shearing force per unit area required to produce a unit rate of shear per unit thickness of fluid (Fig. 2.1).

The viscosity of straight run bitumen may be determined at 135°C in centistokes following the procedure given in IS:1206 (Part 3) or at 60°C, in poises following the procedure given in IS:1206 (Part 2).


TOP PLATE MOVES WITH VELOCITY (V)
AREA (A)
THICKNESS OF LIQUID(d) WITH COEFFICIENT OF VISCOSITY (η)
FIXED
FORCE (F)

For simple liquids $F = \eta \frac{A.v}{d}$ i.e. $\eta = \frac{F.d}{A.v}$

Fig. 2.1. Concept of Viscosity

The unit of measurement of dynamic or absolute viscosity in CGS and SI units are as under :

CGS unit : (1 dyne - sec/cm^2), termed as a poise (P)

SI unit : (1 Newton - sec/m^2), termed as a centistoke (cst) equivalent to 10 P.

Kinematic viscosity (y) is the quotient of the dynamic viscosity (η) and the density of the fluid (p).

Thus :

$$\gamma = \frac{\eta}{\rho}$$

Viscometers work on common principles, though they differ in detail. The liquid under test is poured to a specified level into a container, surrounded by a water or oil bath, which is temperature controlled. A small orifice controlled by a simple valve allows the liquid to discharge. On opening the valve, the time in seconds is recorded for a stated quantity of liquid to fill-up into a measuring container below. Calibration procedures enable the viscosity to be computed from the measured time in seconds.

2.1.5.2. Penetration : The penetration of a standard needle into the bitumen under standard conditions of load, time and temperature, is an indirect measure of viscosity. The penetration is expressed in units of 0.1 mm of the standard needle. The principle is illustrated in Fig 2.2. The standard conditions are a load of 100 gm, time of 5 sec and a temperature of 25°C. The test is described in IS:1203.

A bitumen of penetration 80/100 signifies a range of penetration between 80 and 100 units i.e., to 10 mm. The lower the penetration value, the harder is the grade of bitumen. The penetration test is empirical.

2.1.5.3. Softening point : A thick viscous material, like, bitumen does not have a well-defined softening point. However, a standard test procedure determines the temperature at which the bitumen becomes soft enough to pass a standard ball through a disc of bitumen contained in a ring. The test is known as the "Ring and Ball Test". A brass ring containing the bitumen sample is suspended in water or glycerine

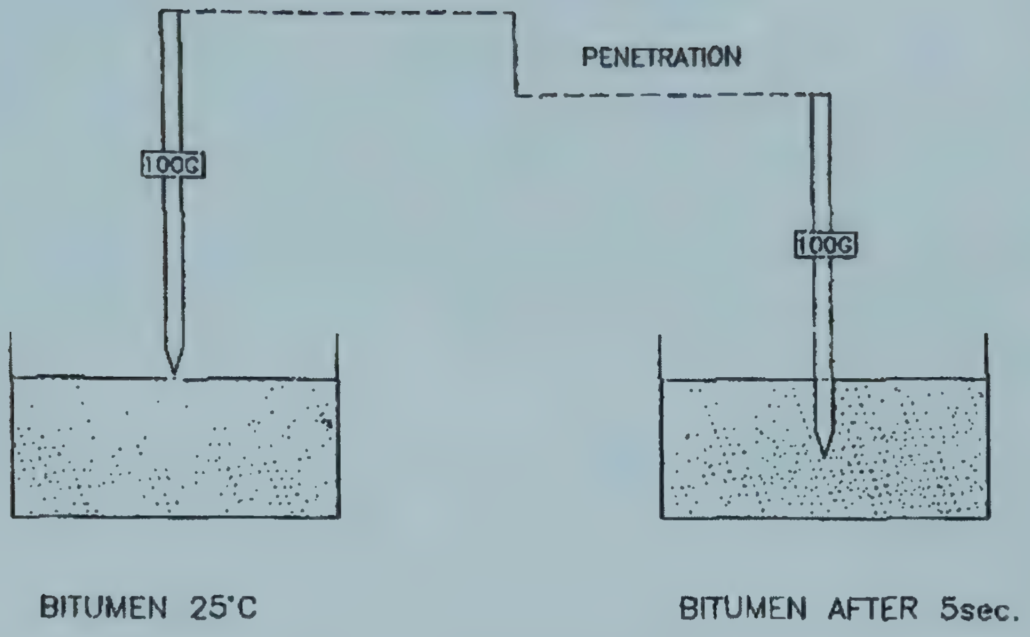
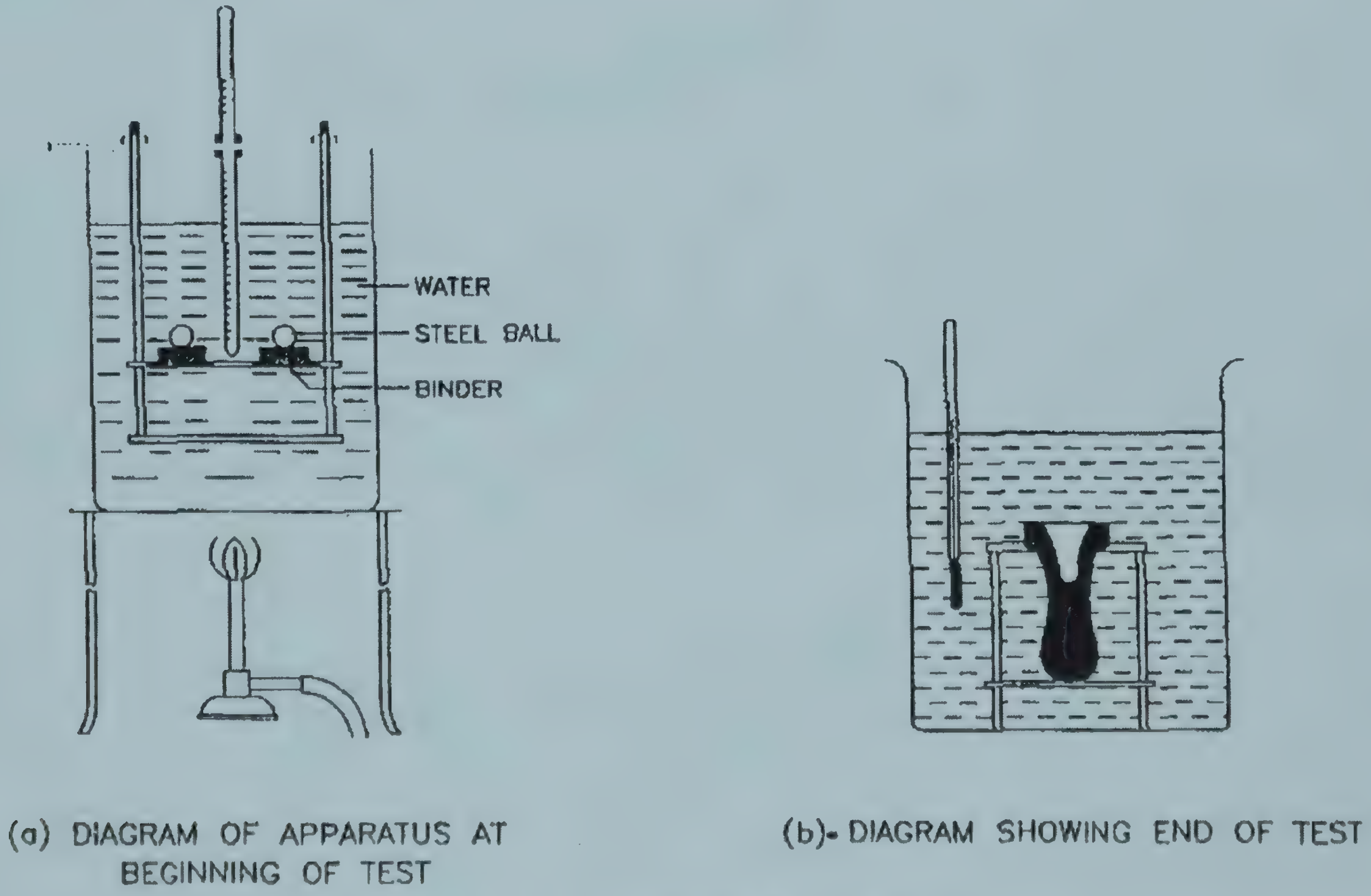


Fig. 2.2. Penetration Test

at a given temperature. A steel ball is placed on the disc of bitumen (Fig. 2.3). The liquid medium is then heated at a rate of 5°C increase per minute. The temperature at which the softened bituminous material touches the bottom metal plate is recorded as the softening point. Bitumen of grade 30/40 has a softening point of 50-60°C, whereas, the softest grade 180/220 has a softening point of 30°-45°C. 80/100 penetration bitumen has a softening point in the range of 35-50°C, and 60/70 pen grade has a softening point of 40-55°C.



(a) DIAGRAM OF APPARATUS AT BEGINNING OF TEST

(b)- DIAGRAM SHOWING END OF TEST

Fig. 2.3. Softening Point Test

2.1.5.4. The Fraass Breaking Point Test : The Fraass breaking point test (IS:9381) is one of the very few tests which can be used to describe the behaviour of bitumens at low temperatures (as low as -30°C). Although, not generally applicable to Indian conditions, the test is a useful research tool which determines the temperature at which bitumen reaches a critical stiffness and cracks. A number of countries with very low winter temperatures, for example Canada, Finland, Norway and Sweden, have maximum allowable Fraass temperatures for individual grades of bitumen.

2.1.5.5. Ductility : The ductility of a bitumen is a measure of its ability to deform, when stretched at a constant rate, at a constant temperature, without fracturing. A material which is not adequately ductile would break prematurely under load, a property which would not be desirable in a good flexible pavement, not-the-least because surface water would then be able to penetrate through the resulting cracks in the pavement layers.

Ductility is measured by determining the distance in cm that a standard briquette of bitumen, necked to a cross-section of 1 sq.cm, will stretch without breaking when elongated at a rate of 5 cm per min. at 27°C (Fig. 2.4). The test procedure is described in IS:1208.

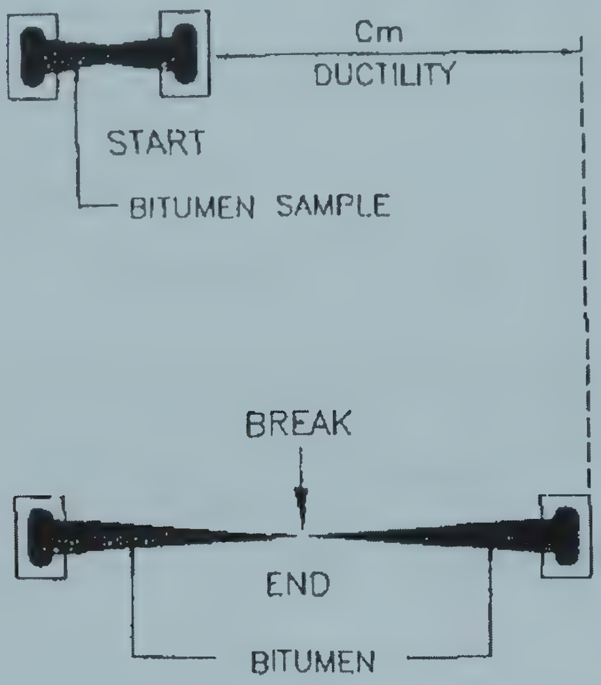


Fig. 2.4. Ductility Test

2.1.5.6. Thin film oven test (TFOT) : In this test, a sample of bitumen is subjected to hardening conditions, as would be expected during hot mixing operations. A 50 ml sample of bitumen is placed in a flat bottomed sample pan having 140 mm inside diameter and 10 mm deep. The weighed sample and container are placed in a shelf which rotates @ 5 to 6 rpm for 5 hours in a ventilated oven (Fig. 2.5) maintained at 163°C. The loss in weight of the sample is expressed as a percentage of the original weight. The hardened bitumen sample is then poured into a container for use in the viscosity or penetration test. The change in test result, before and after ageing, is a measure of the effect of the ageing. The test is carried out as per the procedure given in IS:1212.

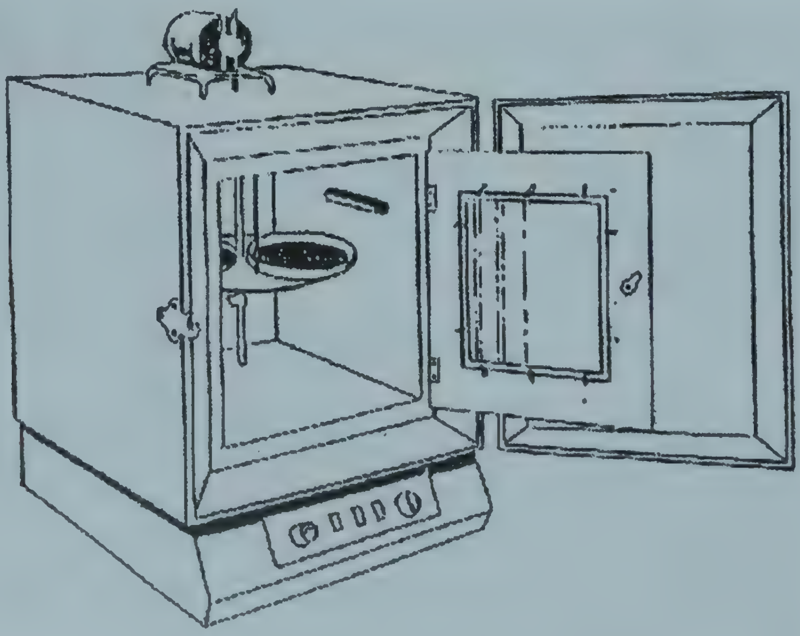


Fig. 2.5. Thin Film Oven Test

2.1.5.7. Rolling thin film oven test (RTFOT) : This test is commonly used for grading of bitumen on the basis of "aged residue" (AR) and viscosity. In the test, a specified amount of bitumen is poured into a specially designed bottle, which in turn is placed inside a rack that rotates at a prescribed rate around a horizontal axis, inside an oven (Fig. 2.6) at a constant temperature of 163°C. The rotating bottle continuously exposes fresh films of bitumen. Once in each rotation, the orifice of the bottle passes before an air jet which blows out accumulated vapours from the bottle. The RTFOT is considered to simulate the short term ageing or hardening that occurs during the mixing process. The residue is tested as in the TFOT.

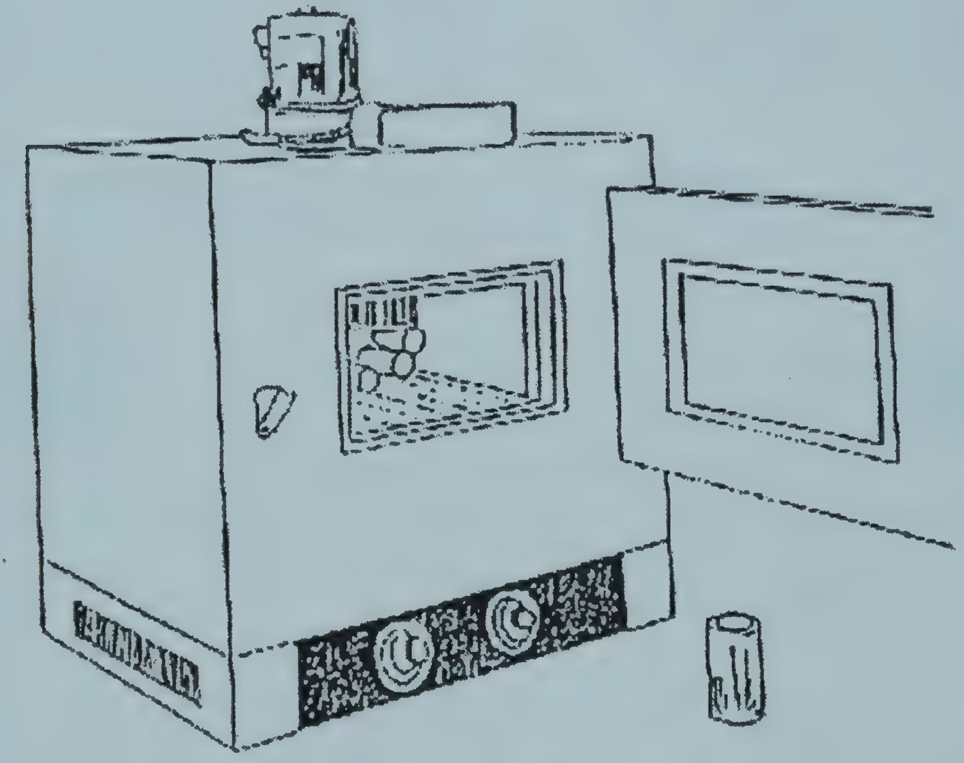


Fig. 2.6. Rolling Thin Film Oven Test

2.1.5.8. Heat stability : When bitumen is heated, it releases fumes which are combustible. The "Flash Point" of bitumen is that temperature at which the fumes ignite in an instantaneous flash in the presence of a flame (Fig. 2.7). If further heating is continued in the presence of the flame, the vapours eventually ignite and continue to burn. The temperature at which the vapours continue to burn for at least 5 sec. is known as the Fire Point. IS:1209 gives the test procedure.

As bitumen is heated, the vapours are released causing reduction in its weight. According to IS:1212, bitumen is heated continuously for 5 hours at a temperature of 163°C and the percentage loss in weight is determined. Indian specifications stipulate a maximum allowable loss for straight-run bitumens, of 2 per cent. The penetration of the residual bitumen is also determined (This procedure is analogous to TFOT and RTFOT above).

2.1.5.9. Solubility : Bitumen is soluble in Carbon Disulphide (CS_2). Insolubles indicate the presence of mineral matter. Indian specifications require 99 per cent solubility. IS:1216 gives the test procedure. For reasons of health and safety, tricholoroehtylene is usually used in preference to carbon disulphide in the solubility test.

2.1.5.10. Specific gravity : The Specific Gravity of bitumen is normally in the range of 0.97 to 1.02. IS:1202 gives the test procedure.

2.1.6. Grading of straight-run bitumens : The "straight-run petroleum bitumen" used for road works is also termed as "paving bitumen". As per IS:73 on Paving Bitumen Specification, there are two types of

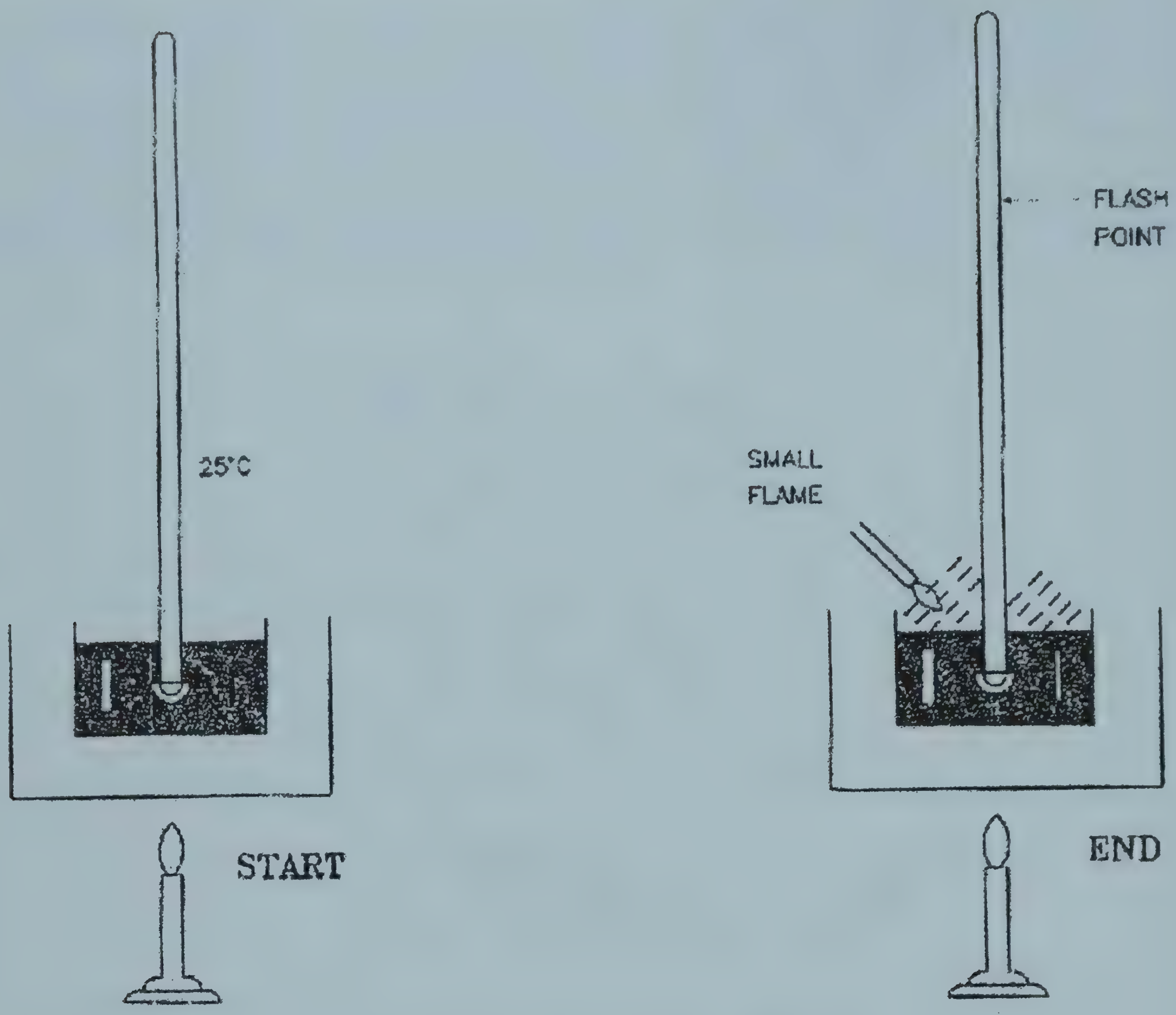


Fig. 2.7. Thin Film Oven Test

straight-run bitumen : Type 1 and Type 2. Their grading is based on results of standard penetration test, already described in para 2.1.5.3. Type 2 relates to bitumen derived from petroleum crude with excessive wax content. The six grades are as under:

Straight Run Bitumen Types

The grades for Paving Bitumen Type 1 are:

Grade	Penetration Test Values
S 35	30/40
S 45	40/50
S 55	50/60
S 65	60/70
S 90	80/100
S 200	175/225

Similarly, the grades for Paving Bitumen Type 2 are:

Grade	Penetration Test Values
A 35	30/40
A 55	50/60
A 65	60/70
A 90	80/100

As mentioned earlier, the straight-run bitumen Type 2 is not recommended for paving purposes, because of excessive wax content and low ductility values which would adversely affect the permanence of coating of aggregates by bitumen.

The penetration test, being empirical, is now considered to be inadequate to characterise the bitumen. A more scientific method is to classify bitumen according to its viscosity at 60°C. A standard unit of measurement of viscosity is the poise.

There are two series of viscosity grades by which bitumen may be classified. One grade consists of a series AC - 2.5, AC - 5, AC - 10, AC - 20, AC - 30 and AC - 40, the term AC standing for Asphaltic Cement (the American term for bitumen), and the numbers indicating the viscosity in hundreds of poises at 60°C. The other series consists of grades AR - 1000, AR - 2000, AR - 4000, AR - 8000 and AR - 16000, with the term AR standing for Aged Residue and the numerical values indicating the viscosity in poises measured after the bitumen has been subjected to the Rolling Thin Film Oven Test.

Since the penetration test is empirical and the viscosity test is fundamental, there is no direct relationship between them. Such a relationship varies for different bitumens from different crude sources. An approximate correlation is presented in Fig. 2.8.

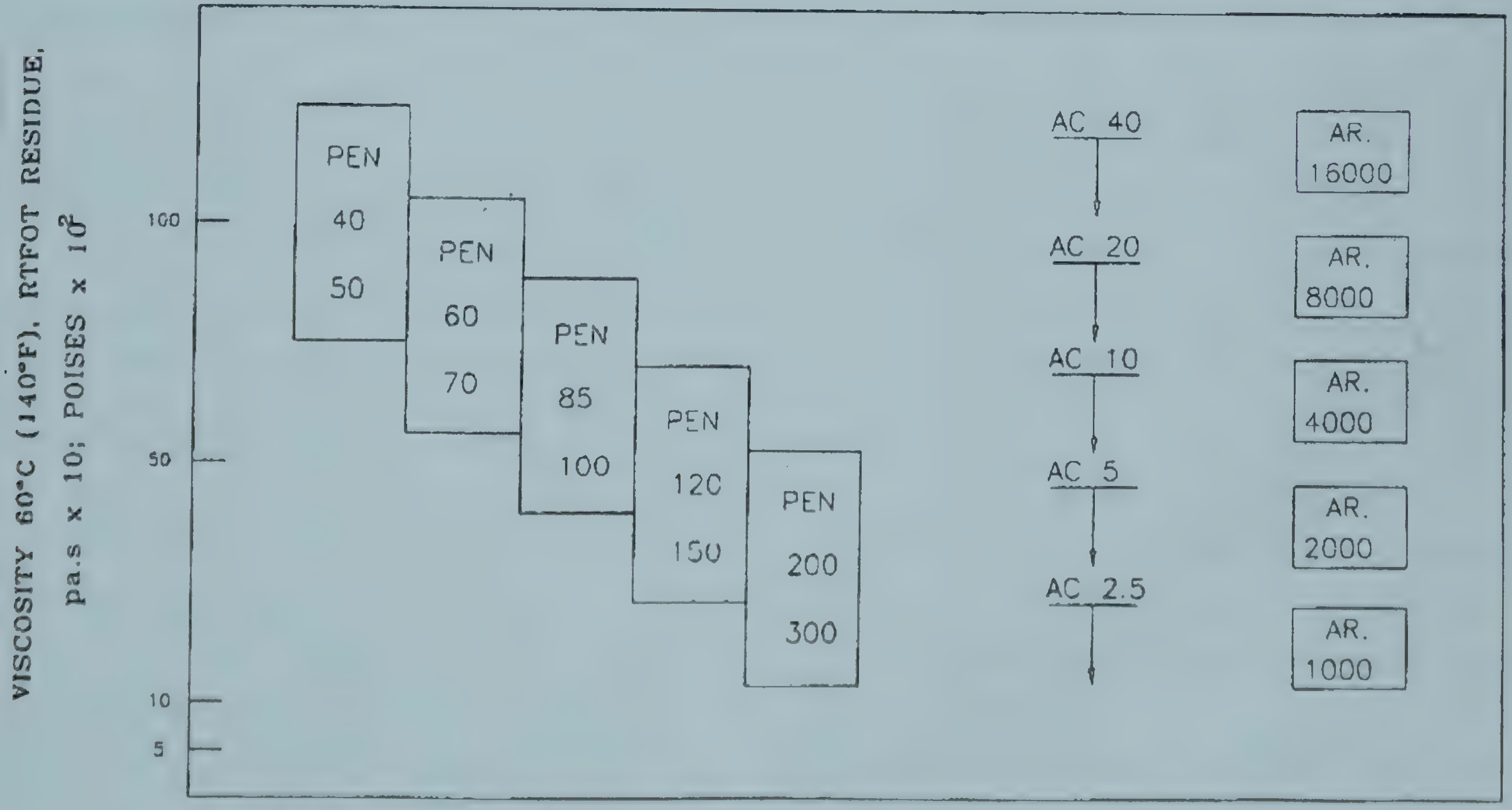


Fig. 2.8. Comparison of Penetration Grades and Viscosity Grades of Bitumen

It may be pointed out here that the minimum ductility requirements on original bitumen sample as per IS:73 appear to be on the lower side especially for Type 2 paving bitumen when compared to international standards.

As per the American Specification (ASTM D3381-1992) the various requirements for paving bitumen are given at Table 2.2. It may be noted from this Table that the ductility requirements have been laid down on the basis of results of tests performed on residue from thin film oven test. The minimum ductility requirements given in Table 2.2 are considered suitable for Indian conditions also.

Table 2.2. Requirements for Asphalt Cement Viscosity Graded at 140°F (60°C) (ASTM D3381)

Note : Grading based on original asphalt

Test:	Viscosity Grade					
	AC-2.5	AC-5	AC-10	AC-20	AC-30	AC-40
Viscosity, 140°F(60°C), P	250±50	500±100	1000±200	2000-400	3000-600	4000-±800
Viscosity, 275°F (135°C) min, cSt	125	175	250	300	350	400
Penetration, 77°F(25°C), 100 g, 5s, min	220	140	80	60	50	40
Flash point, Cleveland open cup, min, °F (°C)	325(163)	350(177)	425(219)	450(232)	450(232)	450(232)
Solubility in triehloroethylene, min %	99.0	99.0	99.0	99.0	99.0	99.0
Tests on residue from thin-film oven test: Viscosity, 140°F(60°C), Max, P	1250	2500	5000	10000	15000	20000
Ductility, 77°F(25°C), 5 cm/min, min, cm	100[A]	100	75	50	40	25

[A] If ductility is less than 100, material will be accepted if ductility at 60°F (15.5°C) is 100 minimum at a pull rate of 5 cm/min

2.1.7. Sampling and criteria for conformity : It is necessary that, in any consignment of bitumen of a specified grade, the quality of the bitumen should be evaluated by running the necessary classification tests on selected samples, as per the details given in IS:73. The three tests recommended by IS:73 are penetration, ductility and softening point.

2.2. Modified Petroleum Bitumens

2.2.1. General : The straight-run bitumen, as obtained from the fractional distillation of crude petroleum, can be suitably modified to meet the specific requirements for a particular road construction operation.

The more commonly used modifications, to avoid heating to high temperatures are produced by using solvents, like, Naphtha, Kerosene and Diesel/Lubricating oil to produce bituminous cutbacks and by way of forming bituminous emulsions in water. These are dealt with in some detail in paras 2.2.2 and 2.2.3. Out of these two liquid bituminous materials viz., cutbacks and emulsions, the use of emulsions is preferred all over the world. This preference of emulsions over cutbacks is based on the fact that cutbacks are environmentally hazardous due to the presence of highly volatile solvents, like, naphtha, kerosene, etc. These solvents may find their way to water sources, and contaminate them.

The internal structure of petroleum bitumen can be modified with a number of chemical modifiers, like, rubbers, polymers, resins, etc. mainly with the objective of extending the service life of a pavement.

While liquid bitumens, like, cutbacks and emulsions, particularly emulsions, are being extensively used because little or no heating is needed, the economic justification for using chemical modifiers needs to be established. The additional cost of modifiers has to be balanced with the extended service life of the pavement.

2.2.2. Cutback bitumens : Being environmentally hazardous and risky in handling, the use of cutback bitumen is discouraged. Globally, bituminous emulsions described in para 2.2.3 are being preferred to cutback bitumen. The petroleum solvents (or distillates or diluents) used for dissolving straight-run bitumen to produce cutback bitumen (Fig. 2.9) are naphtha or gasoline for producing Rapid Curing (RC) cutbacks, kerosene for producing Medium Curing (MC) cutbacks and diesel/lubricating oil for producing Slow Curing (SC) cutbacks. For further detail in respect of properties of the cutback bitumen and composition and quantity of the solvents IS:217 may be referred.

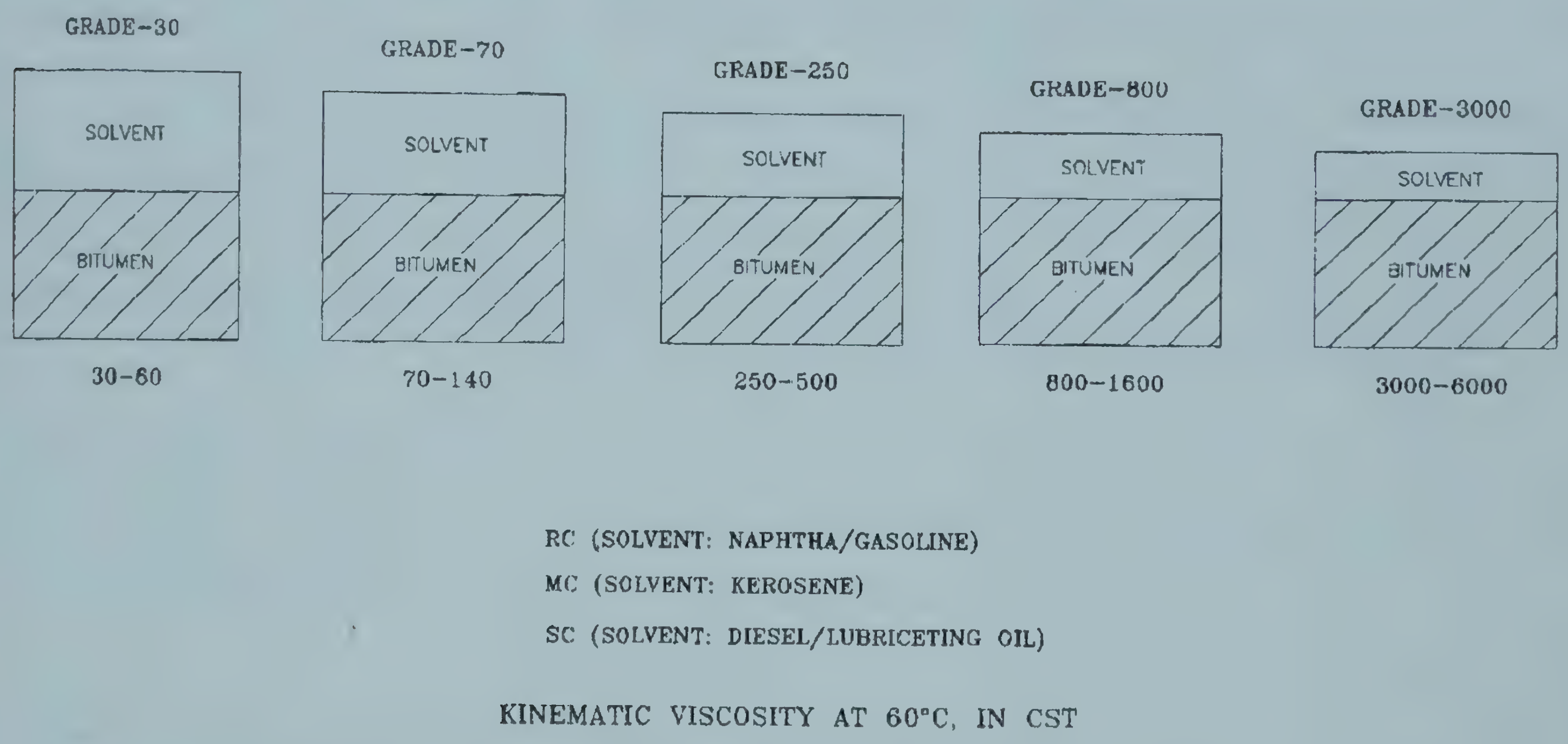


Fig. 2.9. Comparison of Different Grades of Cutback Bitumen

2.2.3. Bituminous emulsions :

2.2.3.1. General : A bituminous emulsion is a liquid bitumen in which a substantial amount of bitumen is suspended in a finely divided condition in an aqueous medium; bitumen is the dispersed phase and water the continuous phase. Stability of an emulsion is achieved by the use of an emulsifying agent contained in the aqueous phase. Based on the type of emulsifier used, bituminous emulsion can be :

1. Anionic - bitumen globules being electro-negatively charged and the aqueous phase, alkaline.
2. Cationic - bitumen globules being electro-positively charged and the aqueous phase, acidic.

In the Nonionic type, bitumen globules are neutral.

Emulsifiers used to manufacture anionic emulsions are normally fatty acids derived from mineral, vegetable or wood sources saponified with sodium or potassium hydroxide. Emulsifiers used to manufacture cationic emulsions are generally amine salts made by reacting hydrochloric acid or acetic acid with an organic amine or diamine.

The emulsion breaks down on contact with aggregate or a road surface. In this process, the particles of bitumen separate from the aqueous component and coalesce into a coherent film of binder. The breaking down process changes the brown colour of the emulsion to black. The water content evaporates, leaving behind the bitumen particles, which get packed together closely. Practically, all grades of bitumen can be emulsified. The bitumen content of an emulsion is in the range of 50-70 per cent, the rest being water.

Because anionic emulsions have a negative charge on the bitumen droplets, they perform best with aggregates having a positive charge (e.g., limestone, dolomite, etc. Cationic emulsions with positive charge on the bitumen perform well with aggregates having a negative charge (e.g., siliceous or granite aggregates).

Depending on how quickly the bitumen particles coalesce, emulsions can be classified as: (i) Rapid Setting (RS); (ii) Medium Setting (MS); (iii) Slow Setting (SS).

A quick type of emulsion (QS) has been developed for slurry seals. High Float (HF) emulsions have the property of permitting a thicker bituminous film on the aggregates.

Emulsions have become popular in the recent past. They enjoy a number of advantages, as under:

(a) They are more tolerant than penetration grade bitumens of the presence of dampness, although they should not be used in the presence of free water, on the road surface or on aggregates.

(b) Because emulsions are of relatively low viscosity at normal temperatures, they eliminate the need to heat the aggregates and binder, and thus they conserve energy.

(c) Their use reduces environmental pollution (especially because, unlike cutback bitumen, they do not release harmful diluents into the environment).

(d) They can be used when the weather is relatively cold.

(e) They are ideal for patching and repair work, particularly because they do not require heating before use.

(f) They are useful for sealing cracks, since they can penetrate fine cracks.

The three types of bituminous emulsions as per IS:8887, Bitumen Emulsions for Roads (Cationic Type) are: Rapid Setting (RS); Medium Setting (MS) and Slow Setting (SS). The classification of bituminous emulsions as per AASHTO/ASTM is more elaborate (also adopted in Ministry's Specifications), as outlined below:

Anionic	**Cationic**
RS - 1	CRS - 1
RS -2	CRS -2
MS - 1	- -
MS - 2	CMS-2
MS - 2h	CMS - 2h
HFMS - 1	- -
HFMS - 2	- -
HFMS - 2h	- -
HFMS 2s	- -
SS - 1	CSS - 1
SS - lh	CSS - lh

Besides the Rapid Setting (RS), Medium Setting (MS) and Slow Setting (SS), the emulsions are further classified by numbers and letters related to viscosity of the emulsions and hardness of the base straight-run bitumen. The letter "C" in front of the emulsion type denotes Cationic while the absence of "C" denotes Anionic. The numbers in the classification relate to the viscosity e.g., MS - 2 is more viscous than MS - 1; the "h" means harder base bitumen and "s" stands for the softer base bitumen. In the anionic grades, the "HF" before the grade indicates high float as measured by the float test. High float types have a gel quality that permits a thicker film of bitumen on the aggregate particles.

With the ever increasing use of polymer modified bitumens, a new set of emulsion grades have been introduced, generally ending in 'p' or 's' e.g. HFRS-2 p or HRRS-2s implies polymer modified emulsions.

In the classification system adopted in the United Kingdom, emulsions are ated as : K types i.e., Cationic or A types, i.e., Anionic. A scale of 1 to 4 is used to reflect the rate of break of emulsions. Fast break is 1 and slow break is 4. For example, a K1 material is a fast breaking cationic emulsion. The percentage bitumen content is also used to specify an emulsion. A K1-70 is a fast setting cationic emulsion which contains 70 per cent by mass of bitumen.

2.2.3.2. Laboratory evaluation of bituminous emulsions : The quality of bituminous emulsions has to be evaluated to ensure that it possesses requisite properties required of the binder for a particular type of field application. The various tests (detailed in IS:8887) for evaluation of the quality of a bituminous emulsion are briefly described below :-

Viscosity Test : The Saybolt Furol Viscometer (IS:3117) is used (Fig. 2.10) for determining the viscosity. The test result is expressed in seconds for the flow of 60 cc of the emulsion sample through a 3.8 mm diameter orifice under the specified conditions of the test.

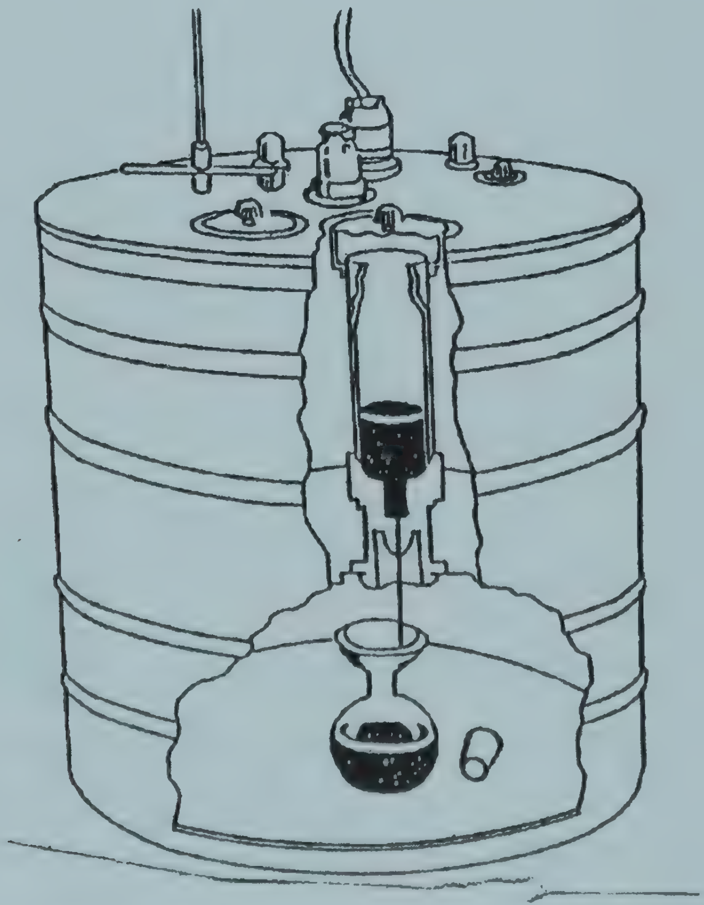


Fig. 2.10. Saybolt Furol Viscometer

Settlement Test : This test provides a measure of settlement that may take place in a sample of emulsion by way of bitumen globules settling out during storage of the emulsion. Two graduated cylinders are taken with a 50 ml sample of emulsion in each. After standing for 5 days, small samples are taken from the bottom and top parts of each cylinder. On heating of the samples, water evaporates leaving behind residue. The difference in weights of residue between top and bottom samples indicates the settlement of bitumen globules.

Storage Stability Test : This is similar to the settlement test except that the samples are allowed to stand only for 24 hours instead of the 5 days.

Classification Test : Distinguishes rapid setting cationic emulsified bitumen from other types by their failure to coat a sand-cement mixture. Pre-weighed amounts of standard sand, portland cement and bituminous emulsion are mixed for 2½ minutes. An excess of uncoated area over coated area of sand is considered as a passing rate for CRS emulsions.

The physical and chemical requirements of bitumen emulsion (cationic type) as per IS:8887-1995 'Bitumen Emulsion for Roads (Cationic Type)-Specification', are shown in Table 2.3.

Table 2.3. Physical and Chemical Requirements of Bitumen Emulsion (Cationic Type) (As per IS: 8887)

Sl. No.	Characteristics	Type of emulsion		
		RS	MS	SS
i.	Residue on 600-micron IS Sieve (per cent by mass, Max)	0.35	0.05	0.05
ii.	Viscosity by Saybolt Furol Viscometer Seconds			
	At 25°C	- -	- -	20-110
	At 50°C	50-400	50-400	- -
iii.	1)Congulation of emulsion at low temperature	Nil	Nil	Nil
iv.	Storage Stability after 24h, percentage, Max	1	1	1
v.	Particle charge	Positive	Positive	Positive
vi.	Coating ability and water resistance			
	Coating, dry aggregate	--	Good	--
	Coating, after spraying	--	Fair	--
	Coating, wet aggregate	--	Fair	--
	Coating, after spraying	--	Fair	--
vii.	Stability to mixing with cement (percentage coagulation)	--	--	2
viii.	Micobility with water	Nil	Nil	Nil
ix	Tests on residue			
	a) Residue by evaporation, per cent, Min	65	65	57
	b) Penetration 25°C /100g/5 sec	60-210	60-210	60-210
	c) Ductility 20°C /cm, Min	75	75	75
	d) Solubility: In tricholoroethylene, Min	97.5	97.5	95.7

1) This requirement shall be applicable only under situations where the ambient temperature is below 15°C

Demulsibility Test : Indicates the relative rate at which the colloidal bitumen globules in RS type will break when spread in thin films on aggregate or soil. $CaCl_2$ causes the minute globules in the emulsion to coalesce. A solution of C_aCl_2 and water is thoroughly mixed with the bituminous emulsion, then it is poured a sieve to determine how much the bitumen globules coalesce.

Cement Mixing Test : This test is used in place of the demulsibility test for slow-setting grades of bituminous emulsion.

Particle Charge Test : Is an identification for Cationic and Anionic Emulsions. Two electrodes (Anode + and Cathode-) are immersed in a sample of bituminous emulsion (Fig. 2.11) and connected to DC electrical source. After half-hour, or after the current has dropped to 2 milli-amperes, it is observed as to which electrode has the deposition of bitumen. If over the cathode, it is Cationic, and vice versa.

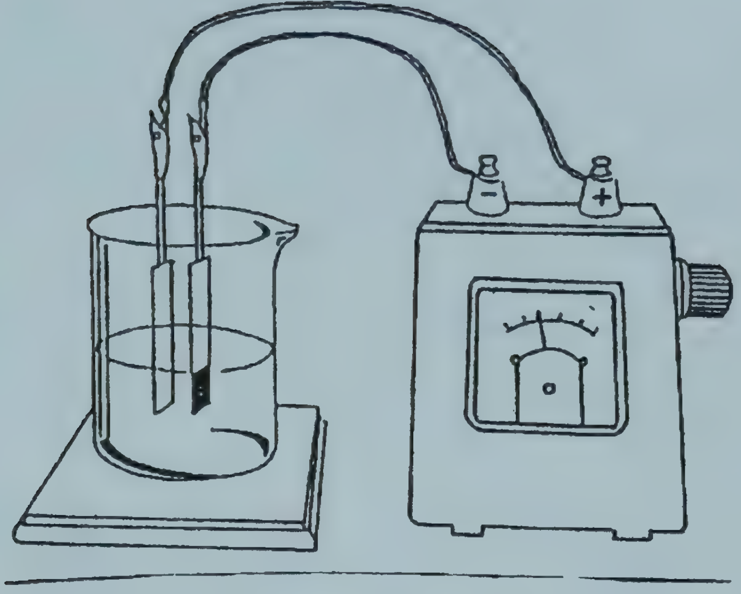


Fig. 2.11. Particle Charge Test

Sieve Test : A specified weight of bituminous emulsion is poured through an 850 micron sieve. For Anionic emulsions, the sieve and retained bitumen are rinsed with a mild sodium oleate solution. For Cationic emulsions, rinsing is with distilled water. After rinsing, the sieve and bitumen are dried in an oven and the relative amount of bitumen retained on the sieve is determined. This test determines the percentage of straight-run bitumen in the form of pieces, strings or large globules which might clog the equipment and to provide non-uniform coatings on aggregate particles.

Distillation Test : Determines the relative proportion of bitumen and water in the emulsion (Fig. 2.12). If the emulsion also contains an oil distillate, this test provides information on the amount of this rial in the emulsion. On the residue of straight-run bitumen, penetration, ductility and solubility tests can be conducted. The test procedure is essentially the same as for cutbacks.

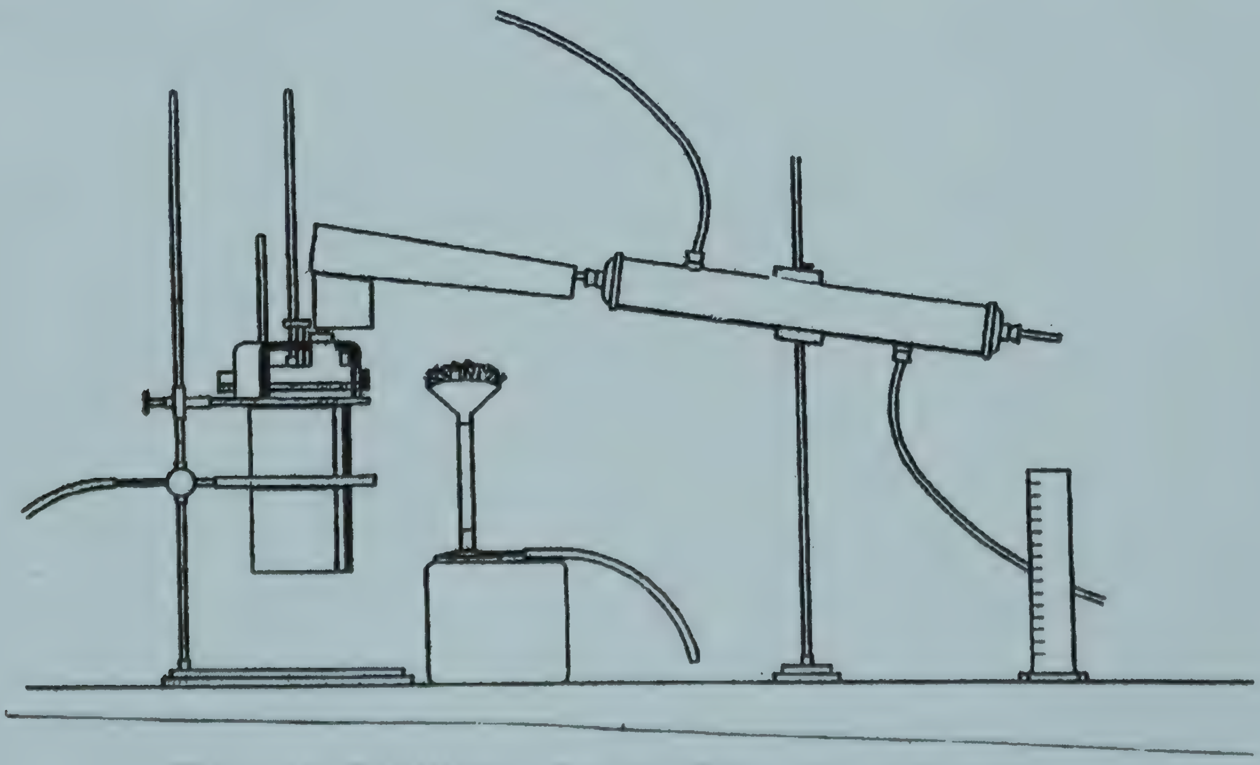


Fig. 2.12. Distillation Test for Bituminous Emulsion

Float Test : This test is performed on the residue from distillation. The test is a measure of the resistance to flow at an elevated temperature. In this test, a test plug is formed by cooling the bitumen residue in a brass collar (Fig. 2.13). The collar is then screwed into the bottom of an aluminium float and placed into a testing bath of water heated at 60°C. The time required for the hot water to break through the plug measured in seconds.

2.2.3.3. Sampling and criteria for Conformity: For checking the quality in any consignment of bituminous emulsion of a specified type and grade, the sampling should be done as detailed in IS:8887. The various tests to be carried out on the selected samples are also outlined in IS:8887. However, the criteria for conformity may be as per ASTM D977 given at Table 2.3(a), as the Indian Standard does not cover all the types and grades incorporated in the revised Ministry's Specifications.

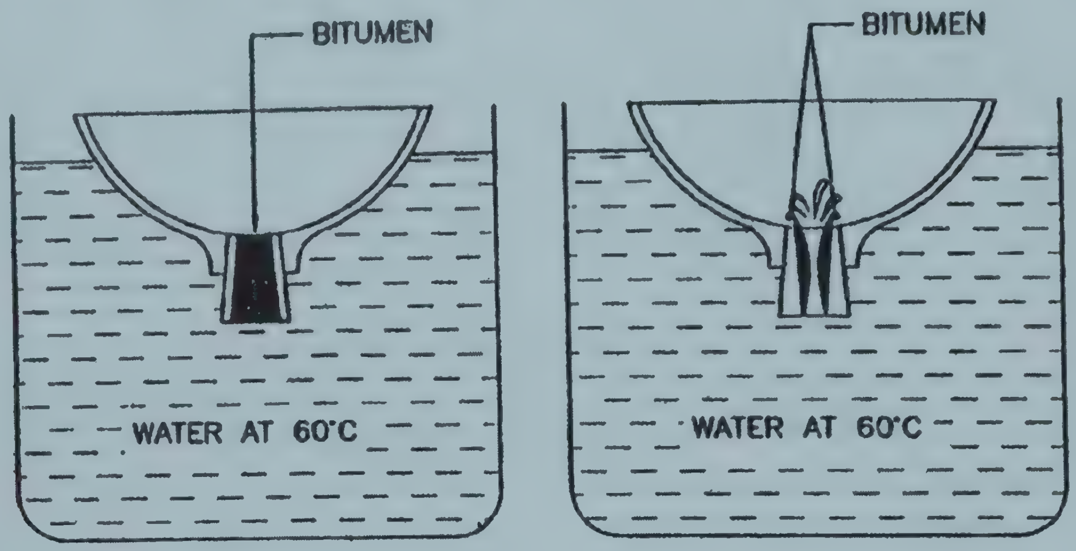


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Fig. 2.13. Float Test

Mixing and Spraying Temperatures

The mixing and spraying temperatures recommended for various grades of bituminous emulsions are given below:

Mixing Temperatures (°C)		Spraying Temperatures-(°C)	
		Road Mixes	Surface Treatments
RS-1	-	-	20-60
RS-2	-	-	50-85
MS-1	10-70	20-70	20-70
MS-2	10-70	20-70	-
MS-2h	10-70	20-70	-
HFMS-1	10-70	20-70	20-70
HFMS-2	10-70	20-70	-
HFMS-2h	10-70	20-70	-
HFMS-2s	10-70	20-70	-
SS-1	10-70	20-70	-
SS-lh	10-70	20-70	-
CRS-1	-	-	50-85
CRS-2	-	-	50-85
CMS-2	10-70	20-70	-
CMS-2h	10-70	20-70	-
CSS-1	10-70	20-70	-
CSS-lh	10-70	20-70	-

Table 2.3 (a) Requirements for Emulsified Asphalt (ASTM D977)

	Rapid-Setting						Medium-Setting					
Type	RS-1		RS-2*		HFRS-2		MS-1		MS-2+		MS-2h	
Grade	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Tests on Emulsions:												
Viscosity, Saybolt Furol at 77°C (25°C), s	20	100	...	...	...	...	20	100	100	...	100	...
Viscosity, Saybolt Furol at 122°C (50°C), s	...	...	75	400	75	400	...	...	...	...	...	...
Storage stability test, 24-h %^	...	1	...	1	...	1	...	1	...	1	...	1
Demulsibility, 35m1, 0.02N CaC1$_2$, %	60	...	60	...	60	...	...	...	...	...	...	...
Coating ability and water resistance:												
Coating, dry aggregate	...		...		...		Good		Good		Good	
Coating, after spraying	...		...		...		Fair		Fair		Fair	
Coating, wet aggregate	...		...		...		Fair		Fair		Fair	
Coating, after spraying	...		...		...		Fair		Fair		Fair	
Cement mixing lost, %	...	...	...	...	...	...	...	...	...	...	...	...
Slave test, %^	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10
Residue by distillation, %	55	...	63	...	63	...	55	...	65	...	65	...
Oil distillate by volume of emulsion, %	...	...	...	...	...	...	...	...	...	...	...	...
Tests on residue from distillation test:												
Penetration, 77°F, (25°C), 100g, 5s	100	200	100	200	100	200	100	200	100	200	40	90
Ductility, 77°F, (25°C), 5 cm/min, cm	40	...	40	...	40	...	40	...	40	...	40	...
Solubility in trichloroethylene, %	97.5	...	97.5	...	97.5	...	97.5	...	97.5	...	97.5	...
Float lost, 140°F (60°C), s	...	...	...	...	1200	...	...	...	...	...	...	...

* RS-2 (ASTM D 977) is more closer to RS-IS: 8887

+ MS-2 (ASTM D 977) is more closer to MS-IS: 8887

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Table 2.3 (a) (Continued)

	Medium-Setting								Slow-Setting			
Type	HFMS-1		HFMS-2		HFMS-2h		HFMS-2s		SS-1*		SS-1h	
Grade	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Tests on Emulsions: -												
Viscosity, Saybolt Furol at 77°C (25°C), s	20	100	100	...	100	...	50	...	20	100	20	100
Viscosity, Saybolt Furol at 122°C (50°C), s	...	...	...	...	...	...	...	...	...	...	...	...
Storage stability test, 24-h %^	...	1	...	1	...	1	...	1	...	1	...	1
Demulsibility, 35m1, 0.02N $CaC1_2$, %	...	...	...	...	...	...	...	...	...	...	...	...
Coating ability and water resistance:												
Coating, dry aggregate	Good		Good		Good		Good					
Coating, after spraying	Fair		Fair		Fair		Fair					
Coating, wet aggregate	Fair		Fair		Fair		Fair					
Coating, after spraying	Fair		Fair		Fair		Fair					
Cement mixing lost, %	...	...	...	...	...	...	...	...	...	2.0	...	2.0
Sieve test, %^	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10
Residue by distillation, %	55	...	65	...	65	...	65	...	57	...	57	...
Oil distillate by volume of emulsion, %	...	...	...	...	...	...	1	7	...	...	...	...
Tests on residue from distillation test:												
Penetration, 77°F, (25°C), 100g, 5s	100	200	100	200	40	90	200	...	100	200	40	90
Ductility, 77°F, (25°C), 5 cm/min, cm	40	...	40	...	40	...	40	...	40	...	40	...
Solubility in trichloroethylene, %	97.5	...	97.5	...	97.5	...	97.5	...	97.5	...	97.5	...
Float lost, 140°F (60°C), s	1200	...	1200	...	1200	...	1200	...	...	...	...	...

^ This test requirement on representative samples is waived if successful application of the material has been achieved in the field.

* SS-2 (ASTM D977) is more closer to SS-IS : 8887

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2.2.4. Polymer/rubber modified bitumens : In addition to bitumen, aggregate and mineral filler in a paving mix, certain modifiers are sometimes added to the bitumen in order to extend the service life of the pavement surface. Such an extended service life is accomplished by controlling the surface cracking, rutting and hardening of the pavement surface due to oxidation and reducing the damage caused by water, etc. There are a number of modifiers which have been tried out, like, polymers (including elastomers), sulphur, organic anti-strip agents, etc.

The advantages in the use of modified bitumen for road works, include the following (IRC:SP:53) :

- Lower susceptibility to daily and seasonal temperature variations
- Higher resistance to deformation at elevated pavement temperature
- Better age resistance properties
- Higher fatigue life of mixes
- Better addition between aggregates and binder
- Prevention of cracking and reflective cracking
- Overall improved performance in extreme climatic conditions and under heavy traffic conditions.

In the field studies that have been carried out, thus far, both natural and synthetic rubber materials have been used in powder form and more effectively in the form of latex or emulsion. Bituminous emulsion can be rubberised by the direct addition of latex; when used in hot bituminous mixtures, tars or cutbacks, provision must be made to remove water.

While rubberised bitumen does improve the properties of bitumen, the high cost of rubberisation of bitumen warrants economic justification before use in bituminous concrete, surface treatments and seal coats.

The requirements of different types of polymer modified binders as per IRC:SP:53 are given in Tables 2.4(a), 2.4 (b) and 2.4(c).

Table 2.4(a). Requirements of Polymer Modified Binders (PMB) (Elastomeric Thermoplastic Based) (IRC: SP: 53)

Designation	Grade and Requirements			Method of Test
	PMB 120	PMB 70	PMB 40	
Penetration at 25°C, 0.1mm, 100g, 5 sec.	90-150	50-89	30-49	IS:1203-1978
Softening Point, (R&B), °C, Minimum	50	55	60	IS:1205-1978
Fraass Breaking Point, °C, Maximum *	-24	-18	-12	IS:9381-1978
Flash Point, °C, Minimum	220	220	220	IS:1209-1978
Elastic Recovery of Half Thread in Ductilometer at 15°C, %, Minimum	75	75	75	ASTM D5976
Separation, Difference in Softening Point, R&B, °C, Maximum	3	3	3	ASTM D5976
Viscosity at 150°C, Poise Test on Thin Film Oven Test Residue, TFOT (IS:9382-1992)	1-3	2-6	3-9	IS:1206-1978
Loss in Weight, %, Maximum	1.0	1.0	1.0	IS:9382-1992
Increase in Softening Point, °C, Maximum	7	6	5	IS:1205-1978
Reduction in Penetration of Residue, at 25°C, %, Maximum	35	35	35	IS:1203-1978
Elastic Recovery of Half Thread in Ductilometer at 25°C, %, Minimum	50	50	50	ASTM D5976-1996

* Relevant to snow bound cold climate areas

Table 2.4(b). Requirements of Polymer Modified Binders (PMB) (Plastomeric Thermoplastic Based) (IRC:SP:53)

Designation	Grade and Requirements			Method of Test
	PMB 120	PMB 70	PMB 40	
Penetration at 25°C, 0.1mm, 100g, 5 sec.	90-150	50-89	30-49	IS:1203-1978
Softening Point, (R&B), °C, Minimum	50	55	60	IS:1205-1978
Fraass Breaking Point, °C, Maximum *	-20	-16	-12	IS:9381-1978
Flash Point, °C, Minimum	220	220	220	IS:1209-1978
Elastic Recovery of Half Thread in Ductilometer at 15°C, %, Minimum	50	50	50	ASTM D5976
Separation, Difference in Softening Point, R&B, °C, Maximum	2	2	2	ASTM D5976
Viscosity at 150°C, Poise	1-3	2-6	3-9	IS:1206-1978
Test on Thin Film Oven Test Residue, TFOT (IS:9382-1992)				
Loss in Weight, %, Maximum	1.0	1.0	1.0	IS:9382-1992
Increase in Softening Point, °C, Maximum	7	6	5	IS:1205-1978
Reduction in Penetration of Residue, at 25°C, %, Maximum	35	35	35	IS:1203-1978
Elastic Recovery of Half Thread in Ductilometer at 25°C, %, Minimum	35	35	35	ASTM D5976-1996

* Relevant to snow bound cold climate areas

Table 2.4(c). Requirements of Rubber Modified Binders (RMB) (Modified Crumb Rubber and Natural Rubber) (IRC:SP:53)

(Table 500.46 of M/o. RT&H's Specifications for Road and Bridge Works)

Designation	Grade			Method of Test
	CRMB-60	CRMB-55	CRMB-50	
Penetration at 25°C, 0.1mm, 100g, 5 sec.	50-70	50-60	40-60	IS:1203-1978
Softening Point, (R&B), °C, Minimum	50	55	60	IS:1205-1978
Elastic Recovery of Half Thread in Ductilometer at 15°C, %, Minimum	55	55	50	ASTM: D5976-1996
Test on Thin Film Oven Test Residue, TFOT (IS:9382-1992)				
Reduction in Penetration at 25°C, % Maximum	60	60	60	IS:1203-1978
Increase in Softening Point, (R&B), °C, Maximum	5	5	5	IS:1205-1978
Elastic Recovery of Residue of Half Thread in Ductilometer at 15°C, %, Minimum	35	35	35	ASTM D5976-1996

CRMB - Crumb Rubber Modified Bitumen

Sulphur as a chemical modifier, in relatively high amounts (15 to 18 per cent) increases the workability of the binder and increases the stiffness modulus of a bitumen mixture. Higher penetration grades of bitumen can be used because of the modifying properties of the mixture. The disadvantages of sulphur are its high cost (because of high contents of sulphur) and environmental hazards.

The most common thermoplastic copolymer used to produce a modified bitumen is the Ethylene Vinyl Acetate (EVA). The effect of EVA is to increase the viscosity of the bitumen, but has little effect on the elastic properties of the bitumen. It is used in small quantities, e.g., 5 per cent in 60/70 penetration grade bitumen. Addition of EVA increases the softening point, increases "stability" and reduces the "flow". EVA is generally used as a modifier with bitumen for cold weather conditions.

The more common examples of synthetic rubbers as modifiers are styrene-butadiene-styrene (SBS) block copolymer and styrene-butadiene rubbers (SBR).

For surface dressing applications at difficult sites e.g., roundabouts and bends, the use of polymer modified binders is desirable. Emulsions are often made of copolymer bitumens that are also used for surface dressing applications.

Epoxy resins appear to be excellent binders since they can increase the stiffness modulus and strength of the bituminous mixture substantially. However, they are expensive and, because they are 2-component (the two liquid components are a resin and a hardener) thermosetting binders, they are vulnerable to delays in construction works. They are generally only used as hot mixed materials for specialist applications, such as, bridge deck surfacings and container terminals. Polyurethane resins have been developed as an alternative to epoxy resins for surface dressing requiring high skid resistance.

Other commonly used additives to bitumen are mainly to promote proper coating of aggregates and adhesion, particularly in damp or wet conditions and to increase the resistance of bitumen to stripping of the aggregate by the action of water. The adhesion of bituminous material (to the aggregate surface) depends on its chemical make-up, e.g., on 'dipole molecules', which act as if they have positive and negative ends and, therefore, are able to satisfy the energy demands of the aggregate. Therefore, the additives for promoting adhesion imply adding the required type of molecule to bitumen. Such additives include fatty acids, various soaps particularly soaps of heavy metals, basic dyes, fatty amines, amine acetates and hydrochlorides, etc. Guidelines on the quality and quantity of anti-stripping agent to be added when aggregates are hydrophilic in nature are given at ***Appendix-1***. "Anti-stripping" materials of this type are added to cutback bitumen to promote wet coating and improve adhesion. For straight-run bitumens, a heat-stable additive is required. More recently, the addition of asbestos fibres or fibreglass has been tried out successfully. Glass-fibre has been used in special applications for sealing surface cracking and reinforcing surface dressings. Bitumen impregnated glass-fibre mats have also been used as Stress Absorbing Membrane Interlayer (SAMI) over joints or wide cracks in concrete pavements, prior to overlaying, as part of a system for retarding reflection cracking. The use of polypropylene fibres is limited with conventional bituminous materials since mixing temperatures must be kept below 140°C. Fibres have been found to be very effective at minimising binder drainage in stone mastic bitumen. Cellulose and alumino-magnesium silicate fibres have been used in road trials; glass-fibre, steel wool or asbestos are used in some countries. The addition of fibres may also improve other mechanical properties but the effect is hard to isolate from the effect of the higher binder contents associated with the use of fibres.

Additives have also been developed to give a coloured surface rather than a dark surface.

The various types of additives for bitumen modifications and their indicative closes are tabulated in Table 4.33 in Chapter 4 or this Manual. The modified bitumen should preferably be blended at or near a hot mix plant site or supplied hot in tankers or if supplied in drums, should be agitated in melted condition with suitable device for 10 to 15 minutes before use.

2.3. Selection of Bituminous Binder

2.3.1. Selection of penetration grade bitumen for bituminous mixtures : Bitumens in India are classified by penetration (IS:73), in common with practice in the UK (BS:3690), the rest of Europe (pr EN 12597), and many other countries in the world. Prior to 1993, the USA also used a penetration graded classification (AASHTO M20) as well as a viscosity graded classification (AASHTO M226).

Given that bitumens in India are classified by penetration, guidelines for selection must inevitably, at present, refer to, and be based upon, the penetration grades available. There are serious drawbacks with this approach:

- the penetration test is empirical, and thus any relationship between bitumen penetration and mixture performance has to be gained by experience.
- the relationship between the test result (penetration) and mixture performance may not be very good.
- the existing tests do not give results over the entire range of typical pavement temperatures (the standard penetration test measures consistency only at 25°C). Viscosity, although a fundamental measure of flow, provides information, at higher temperatures, typically 60°C.
- the existing tests do not adequately characterise the performance of polymer modified bitumens.

The serious limitations of this approach were recognised in the USA, and, since 1993, a performance graded Specification for bituminous binder has been available. This requires new tests and equipment not currently available in India, but it is a long term objective for India to adopt this approach ultimately. Further consideration of a performance graded binder Specification for India is given in para 2.4.

In the meantime, guidelines for selection of an appropriate grade of bitumen are given in Table 2.5 based upon the penetration grades available.

Penetration grade bitumens are specified in Clauses 507 (Dense Graded Bituminous Macadam), 508 (Semi-Dense Bituminous Concrete), 509 (Bituminous Concrete), 510 (Surface Dressing), 511 (Open-graded Premix Surfacing), 512 (Close-graded Premix Surfacing), 513 (Seal Coat) and 520 (Sand Asphalt Base course). Polymer modified bitumens are considered in Clause 521 (Modified Binder) of the Ministry's revised Specifications 2001. In Table 2.5 the selection of bituminous binder is based on climatic conditions and intensity of traffic.

Table 2.5. Recommendations for Selection of Binder Penetration Grade for Roads carrying 10 to 30 x 10^6 Equivalent Stand Axles (esa)

T_{max}(°C)[1] →	<20	20 to 30	30 to 40	40 to 50
T_{min}(°C)[1] ↓		Pentration Grade of Bitumen[3,4]		
-10 to 0	90	90	55 or MPB[5]	55 or MPB[5]
0 to 10	90	90	55	55 or MPB[5]
10 to 20	90	65	45 or 55	45
> 20	--	65	45	35

Notes:

[1] T_{max} = Highest monthly average maximum temperature for project location.

[2] T_{min} = Lowest monthly average minimum temperature for project location.

[3] Penetration Grades are those defined in, IS:73.1992 (e.g. 90 refers to 80/100 pen)

[4] Select one grade softer if traffic < 10 x 10^6 esa[6/7]

[4] Select one grade harder if traffic > 30 x 10^6 esa[6/7] of revised Ministry's Specifications.

[5] A Specification for polymer modified bitumens is given in Clause 521 of revised Ministry's Specifications.

[6] Within the overall limits of penetration between 30 and 100.

[7] Except where T_{max} - T_{min} is greater than 30°C.

Choice of binder is also dependent upon a number of other factors, of which the following are particularly important:

4. mixture type (e.g. 1 dense/open graded);
5. position in the pavement.

With regard to the latter, there is evidence that 40/50, 60/70 and 80/100 penetration grade bitumens in the surface of wearing courses tend to harden to a similar viscosity within a short time in tropical environments. Preferred grades, therefore, exist for certain mixture types/pavement locations, for example 65 pen grade bitumen for dense graded bituminous concrete wearing course. Similarly, it is unlikely that the performance benefit of a polymer modified binder would justify the additional cost below the wearing course layer.

The choice of binder will be dictated by the specific requirements of the Contract, particularly traffic, climate and the aggregates proposed for use. Mastic asphalt is a special case, and the special binders required for this material are specified in Clause 515 of the Ministry's Specifications 2001.

2.3.2 Selection of bituminous binder for surface dressing : The correct choice of binder for surface dressing is critical. Penetration grade, cutback or emulsion may be used. The binder must :

(i) be capble of being sprayed;

(ii) 'wet' the surface of the road in a continuous film;

(iii) not run off a cambered road or form pools of binder in local depressions;

(iv) 'wet' and adhere to the chippings at road temperature;

(v) be strong enough to resist traffic forces and hold the chippings at the highest prevailing ambient temperatures;

(vi) remain flexible at the lowest ambient temperature, neither cracking nor becoming brittle enough to allow traffic to 'pick-off the chippings;

(vii) resist premature weathering and hardening

The factors to be taken into account in selecting an appropriate binder are :-

1. **The road surface temperature at the time the surface dressing is undertaken:**

   For penetration grade and cut-back binders, the viscosity of the binder should be between 10^4 and 7×10^5 centistokes at the road surface temperature.

2. **The nature of the chippings:**

   If inherently dusty chippings are anticipated and no pre-treatment is planned, the viscosity of the binder used should be towards the lower end of the permissible range (under no circumstances may chippings that are heavily contaminated with dust be used). If the binder selected is an emulsion it should be borne in mind that anionic emulsions may not adhere well to certain acidic aggregates such as granites and quartzites.

3. **The characteristics of the road site:**

   Fluid binders, such as, emulsions are not suited to steep crossfalls or gradients since they may drain off the road before 'breaking', leaving insufficient binder to retain the chippings.

4. **The type of binder handling and spraying equipment available :**

   The equipment must be capable of maintaining an adequate quantity of the selected binder at its appropriate spraying temperature and spraying it evenly at the required rate of spread.

5. The cost of the binder available

The amount of binder required per unit area of surface dressing should be estimated and costed.

Fig. 2.14 shows the permissible range of binder viscosity for penetration and cutback grades of bitumen for successful surface dressing at various road surface temperatures. At the lower road temperatures cutback grades of bitumen are most appropriate, whilst at higher road temperatures penetration grade bitumens can be used. The temperature/viscosity relationships shown in Fig. 2.14 do not apply to bitumen emulsions. Guidance on choice of bitumen emulsions for surface dressing and other applications is given in para 2.3.3.

Consideration of the above factors will usually narrow down the choice of binder to one or two options. The final selection will be determined by other factors, such as, the past experience of the surface dressing team.

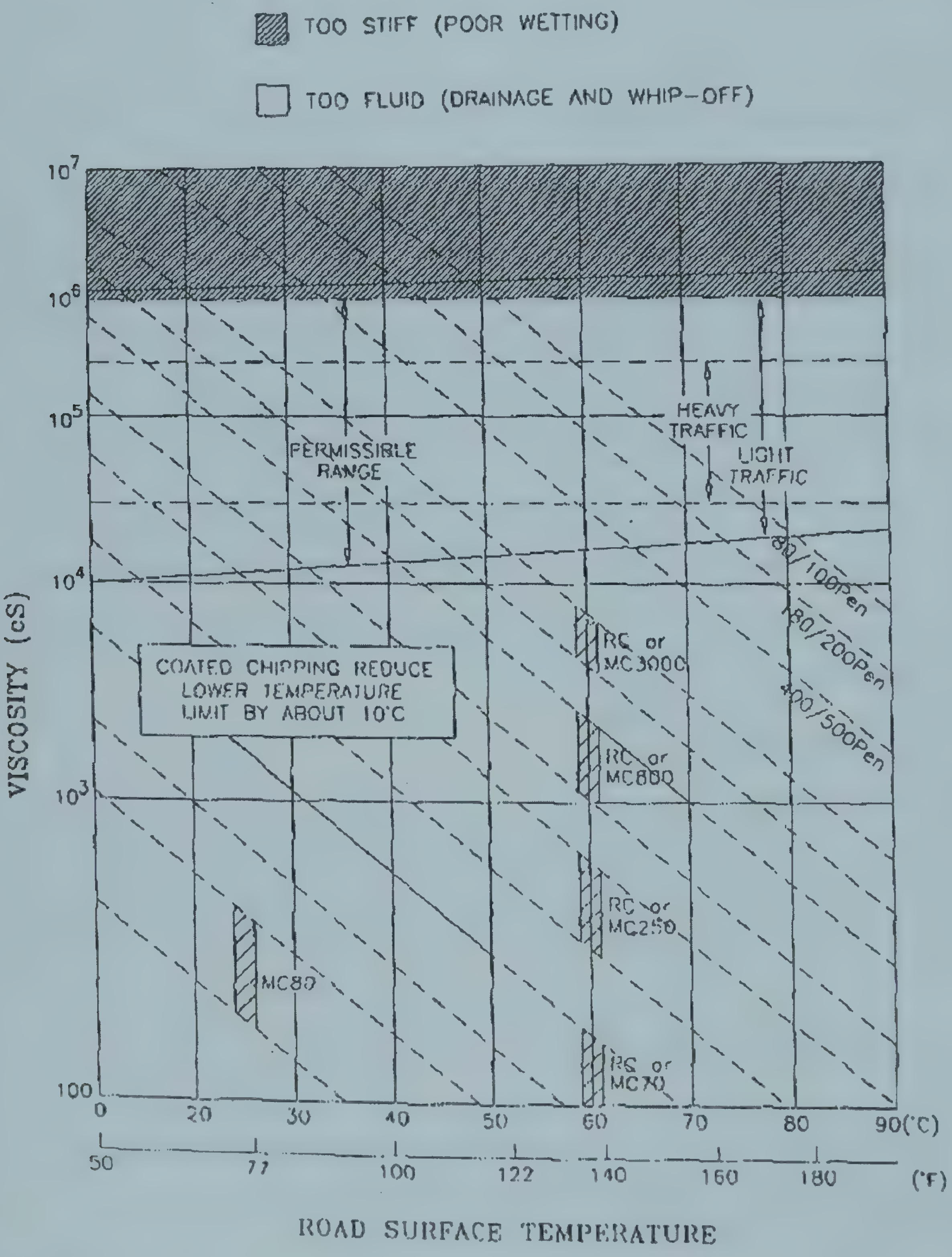


Fig. 2.14. Surface Temperature and Choice of Binder for Surface Dressing (Extracted from Overseas Road Note 31)

2.3.3 Selection of bituminous emulsion : Guidelines presented here are intended to help to select the specific grade and type of bituminous emulsion for the intended use. The first consideration in picking the right type and grade of emulsion is how it will be used. Once this decision is made, other project variables must then be considered. Some other factors that affect the selection are :

- climatic conditions anticipated during construction - the choice of emulsion grade, the design of mix or treatment and the selection of construction equipment should be dictated by the climatic conditions at the time of construction.
- aggregate type, grading and availability.
- construction equipment availability.
- geological location - the hauling distance and, in some cases, water availability are important considerations.
- traffic control - can traffic be detoured or only controlled through the work area?
- environmental considerations.

General guidelines for selecting emulsions are given in Table 2.6 based on ASTM. Notwithstanding, these guidelines, laboratory testing is essential. There is no substitute for a laboratory evaluation of the emulsion and the aggregate proposed for use. Different types and quantities of emulsion should be tried with the aggregate to find the best combination for the intended use.

Table 2.6. Selection of Bituminous Emulsion for Particular Applications

Type of Construction	ASTM D2397 AASHTO M140					
	CRS-1	CRS-2	CMS-2	CMS-2h	CSS-1	CSS-1h
Asphalt Aggregate Mixtures						
Plant Mix (Hot or Warm)						
Plant Mix (Cold)						
Open-graded Aggregate			x	x		
Well-graded Aggregate					x	x
Sand					x	x
Mixed-in-place						
Open-graded Aggregate			x	x		
Well-graded Aggregate					x	x
Sand					x	x
Sandy Soil					x	x
Asphalt Aggregate Applications						
Single and Multiple Surface Treatments	x	x				
Sand Soil	x	x				
Slurry Seal					x	x
Micro-surfacing						x[C]
Sandwich Seal		x				
Cape Seal		x				
Asphalt Applications						
Fog Seal					x[A]	x[A]
Prime Coat					x[B]	x[B]
Tack Coat					x[A]	x[A]
Dust Palliative					x[A]	x[A]
Mulch Treatment					x[A]	x[A]
Crack Filler					x	x
Maintenance Mix						
Immediate use			x	x		
Stockin						

[A] Diluted with water

[B] Mixed-in prime only

[C] Polymer must be added during or prior to emulsification

2.4. Performance Graded Binder Specification

Since 1993, a performance graded Specification has been in use in the USA intended for use with both modified as well as unmodified bitumens. A unique feature of this Specification is that the specified criteria remain constant, but the temperature at which the criteria must be achieved changes for the various grades. The tests specified measure physical properties that can be related directly to field performance by engineering principles, and are conducted at temperatures that are encountered by in-service pavements. A central theme of the Specification is its reliance on testing bituminous binders in conditions that simulate the three critical stages during the binder's life. Tests performed on the original binder represent the first stage of transport, storage, and handling. The second stage represents the binder during mix production and construction and is simulated for the Specification by ageing the binder in a rolling thin film oven. This procedure exposes thin binder films to heat and air and approximates the ageing of the binder during mixing and construction. The third stage occurs as the binder ages over a long period as part of the hot mix bituminous pavement layer. This stage is simulated for the Specification by the pressure ageing vessel. This procedure exposes binder samples to heat and pressure in order to simulate years of in-service ageing in a pavement.

Table 2.7 lists the test equipment required for this performance graded binder specification, together with a brief description of why each test is used and how they provide some indication of binder performance.

Table 2.7. Performance Graded Binder Tests

Equipment	Purpose	Relation to Performance
Rolling Thin Film Oven (RTFO) Pressure Ageing Vessel (PAV)	Simulate binder ageing (hardening) characteristics	Ageing during construction (RTFO) Ageing in service (PAV)
Dynamic Shear Viscometer (DSR)	Measure binder properties at high and intermediate temperatures	Permanent deformation (high temperatures) Fatigue cracking (intermediate temperatures)
Rotational Viscometer (RV)	Measure binder properties at high temperatures	Handling, pumping (flow)
Bending Beam Rheometer (BBR) Direct Tension Tester (DTT)	Measure binder properties at low temperatures	Thermal (low temperature) cracking

The maximum pavement design temperature is used to select a binder which will resist permanent deformation. It is based upon the average of 7 consecutive hottest days ever recorded at the weather station nearest the project site.

The minimum pavement design temperature is used to select a binder which will resist low temperature cracking. It is based upon the lowest air temperature ever recorded at the weather station near the project site.

Like the USA, India experiences a wide range of climatic extremes throughout the sub-continent, particularly with respect to maximum air temperatures, which range from below 20°C in the mountainous regions to above 50°C in the Northern Plains. The American model is considered appropriate for India in the medium to long term, to replace the existing penetration graded Specification. However, India does not experience the same range of extremely low temperatures as the USA, and the low temperature testing (bending beam rheology and direct tension) is, therefore, not appropriate. In their place, the Fraass breaking point test, or penetration at 4°C, could be used to assess the reduced risk of low temperature cracking.

CHAPTER 3

AGGREGATES FOR BITUMINOUS ROADWORK

3.1. Classification and Nomenclature

Stone aggregates form an important constituent of any pavement. They are used for granular bases and sub-bases, bituminous courses and in cement concrete pavements. They impart stability to the pavement and provide abrasion-resistant and anti-skidding properties to the road pavement.

Aggregates are obtained as a result of crushing rock or from natural sources. They may also be obtained from processing slag.

The rocks most commonly encountered in India, together with a brief description of some of their properties and their suitability for use in roadworks are given in Table 3.1.

Table 3.1. Rock Sources in India, their Properties and Suitability for Bituminous Road Works

Sl. No.	Classification of Rock	Type of Rock	Properties Generally Encountered in most Varieties	Suitability for Bituminous Road Works
1	Igneous	Granite	1. Hard, durable. 2. Texture varies from fine-to-coarse-grained 3. Bulk density below 2.8 4. Resistant to abrasion 5. Low water absorption	1. Good for base and wearing courses 2. Can be used with cationic emulsions 3. Can be abrasive to crushing equipment
2	Igneous	Basalt	1. Hard, durable 2. Fine-grained texture 3. Bulk density in the range 2.8 to 3.0 4. Resistant to abrasion 5. Low to medium water absorption	1. Good for base and wearing courses 2. Can be used with cationic emulsions 3. Can.be abrasive to crushing equipment
3	Sedimentary	Sandstone	1. Moderately hard and durable 2. Fine-grained texture 3. Bulk density in the range 2.3 to 2.7 4. Generally, high water absorption	1. Good for base courses 2. Several varieties not suitable for wearing courses
4	Sedimentary	Limestone	1. Reasonably hard and durable 2. Certain varieties liable to polish to a smooth surface under traffic 3. Water absorption may range from low to high 4. Very good adhesion to bitumen	1. Good for base courses 2. Certain varieties unsuitable for wearing courses owing to tendency to polish 3. Suitable for use with anionic emulsions
5	Sedimentary	Kankar	1. An impure form of limestone 2. Some varieties can be soft, not durable and water absorbent	1. Suitable for granular bases 2. Generally not suitable for wearing courses
6	Metamorphic	Quartzite	1. Reasonably hard and durable 2. Fine to medium grained 3. Resistant to abrasion 4. Low water absorption 5. Bulk density in the range 2.5 to 2.8	1. Good for base and wearing courses 2. Can be abrasive to crushing equipment

3.2. Production of Aggregates

3.2.1. General : The production of crushed aggregates from rock usually requires crushers, screens, conveyors and stockpiles. This set-up may be located either near the quarry or near the hot mix plant or at some convenient intermediate site. Adequate space is required to accommodate the above elements in an efficient layout, with ample room for the planned size of aggregate stockpiles. These stockpiles must not interfere with each other, with the operation of the plant, with the vehicles bringing in the raw material, from a quarry or other source, or with the movements and loading of the vehicles taking the finished aggregates away for use elsewhere. Sometimes storage space for stockpiling a reserve supply of raw material for the crusher is also required.

In regard to crushing and screening quarried rock, or boulders, or river cobbles, to produce aggregate for use in a range of pavement materials, having the required sizes, in the required proportions, without waste, and having acceptable particle shape, the following points need to be borne in mind:

1. The rock feed to a primary crusher is often first passed over a "grizzly", or robust coarse grid or screen, in order to remove undesirable undersize rock, weaker material and soil.
2. Crushed material is carried between crushers and screens and stockpiles by means of conveyors. The routing via these conveyors varies considerably. It depends on a number of factors including what is desired of the final products, both in respect of quality and of quantity. For example, for a set of screens being fed from a secondary crusher, the oversize material may be fed back, to go through that crusher a second time; material of certain required sizes may be fed direct to stockpiles; and the remaining material may be fed to a tertiary crusher. The routing and layout of each setup has to be tailor made to suit the site, the nature of the raw material and the project requirements. The aggregate sizes and quantities needed for all pavement construction requirements, not only bituminous materials, have to be considered.
3. It sometimes happens that an unacceptable proportion of flaky finer sizes, which will not be subject to secondary crushing, is produced at the primary crushing stage. If this excess flakiness cannot be rectified by adjustments to the crusher, or to the rock feed, an alternative strategy may be to .screen out the undesirable material after the primary crushing, along with any soil or weathered rock contamination if present. This removed fraction may either be disposed of or it may, if suitable, find another use, such as, an admixture in a sub-base material.
4. Correct choice of type and size of the sets of screens required, and proper operation of these, is of vital importance. The rate of feed to screens from the previous operation invariably varies considerably. If, for part of the time, some of the screens are overloaded with respect to their size (area) and efficient rate of screening, undersize material will be. carried over with coarser sizes. As a result the undersize content of the materials going to stockpiles can vary widely and, depending on how much mixing subsequently takes place, this can be reflected in erratic variability in the combined gradings of material being produced at the mixing plant.
5. Some crushers need to be choke fed to produce aggregate of good shape, so when the rate of feed is too low the shape of the aggregate produced deteriorates. The rate of feed to crushers, and hence their output to screens, is very difficult to keep constant in practice. The capacity of a set of screens should be adequate to efficiently handle the maximum rate of feed that is likely to occur.
6. Another cause of inefficient screening is serious blockage of the openings in the screens by (mainly) elongated particles. \Regular close inspection and cleaning of the screens is required. Holes in screens allow oversize material to pass.
7. A third cause of inefficient screening, with significant carry over of finer sizes, is when wet material is fed to the screens. In such wet material a significant amount of the finer fractions adheres to the coarser sizes and arc not separated during the screening process. This is something that should be taken into consideration when plans are made to continue crushing and screening during a monsoon period, as is sometimes done, in order to build up stocks ready for a high rate of mixture production in the next dry season.

3.2.2. Types of Crushers : The broad types of crushers and their relative advantages are as under :

A. Primary Crushers : Jaw, Gyratory and Impactor Types

In the first stage of crushing, usually the jaw, gyratory and impactor types of crushers are used. Maximum lump size may be as large as 1 metre or even more.

Jaw and gyratory crushers are both capable of handling hard, abrasive rocks and selection is based upon the capacity and maximum lump size. Use of impactor is generally restricted to less abrasive rocks e.g., limestone, but lump sizes higher than lm and capacities upto 1500 tonnes per hour can be achieved.

Generally, for the same capital investment, the jaw crusher will be able to accept the largest lump size. For capacities less than 1000 tonnes per hour, any of the three types could be selected while for a capacity much higher than 1000 tonnes per hour, the choice would normally fall on a Gyratory type crusher.

(a) **Jaw Crusher :** The jaw crusher compresses the rock between a fixed dimension of feed opening jaw to create breaking action. Maximum dimension of feed opening (gape) and the product size is determined by the width of discharge aperture when the jaw has retreated fully (open side setting): Reduction ratio possible is usually in the range 4:1 to 6:1. The moving jaw may be actuated by one of the two principal mechanisms — 'single toggle' and 'double toggle' (Fig. 3.1). In the double toggle system, very powerful compressive forces are created without any abrasive motion; therefore, it is most applicable to the crushing of very strong, abrasive rocks but is more complex, heavy and expensive than a single toggle.

Jaw Crusher is suitable for all hard rocks, generally used for aggregate production.

(b) **Gyratory Crusher :** It consists of a lined inverted conical crushing chamber within which gyrates an upright conical crushing member, the shaft and cone protected by a liner (Fig. 3.2). The frequency of gyrating action is between 100 and 200 cycles/ minute and the 'movement' or 'throw' between 20 and 50 mm.

The main advantage of a gyratory crusher is the much greater unit capacity for any given 'gape' or maximum lump size assuming that this capacity can be fully utilised to justify greater cost. Reduction ratio is 4:1 to 6:1 and the machine is suitable for all hard, abrasive rocks, but not for soft, porous material that may compact in the chamber.

Gyratory crushers are sometimes employed at the secondary stage, (where cone crushers are more common) as they can accept larger lump sizes.

(c) **Impactors :** In a lined chamber, a rotor fitted either with swing. hammers (located by pins) or blow bars of alloy steel (located by mechanised or hydraulic clamps) revolves on a horizontal axis (Fig. 3.3). The hammers or blow bars provide impact to the rock resulting in energy efficient crushing and producing cubical shaped aggregates. Reduction ratios of 20:1 are possible in a single stage; for double • rotor impactors, the reduction, ratio may be as high as 40:1.

Advantages are high reduction ratio, low capital and operating cost, ease of installation and low head room requirement and good product shape. Product size can be varied within limits by changing rotor speed and the clearances between rotor and liners.

A serious limitation is abrasive wear. Abrasive wear requires costly replacement of hammers or blow bars and above all, results in loss of operating time.

Therefore, use of impactors is restricted to crushing of non-abrasive rocks e.g., non-siliceous limestones and dolomites.

Impactors are not suitable for rocks having more than 5 per cent free silica.

Swing hammer type impactors are generally used for the production of the finer sizes of aggregates but impact becomes ineffective at a particle size less than 3 mm.

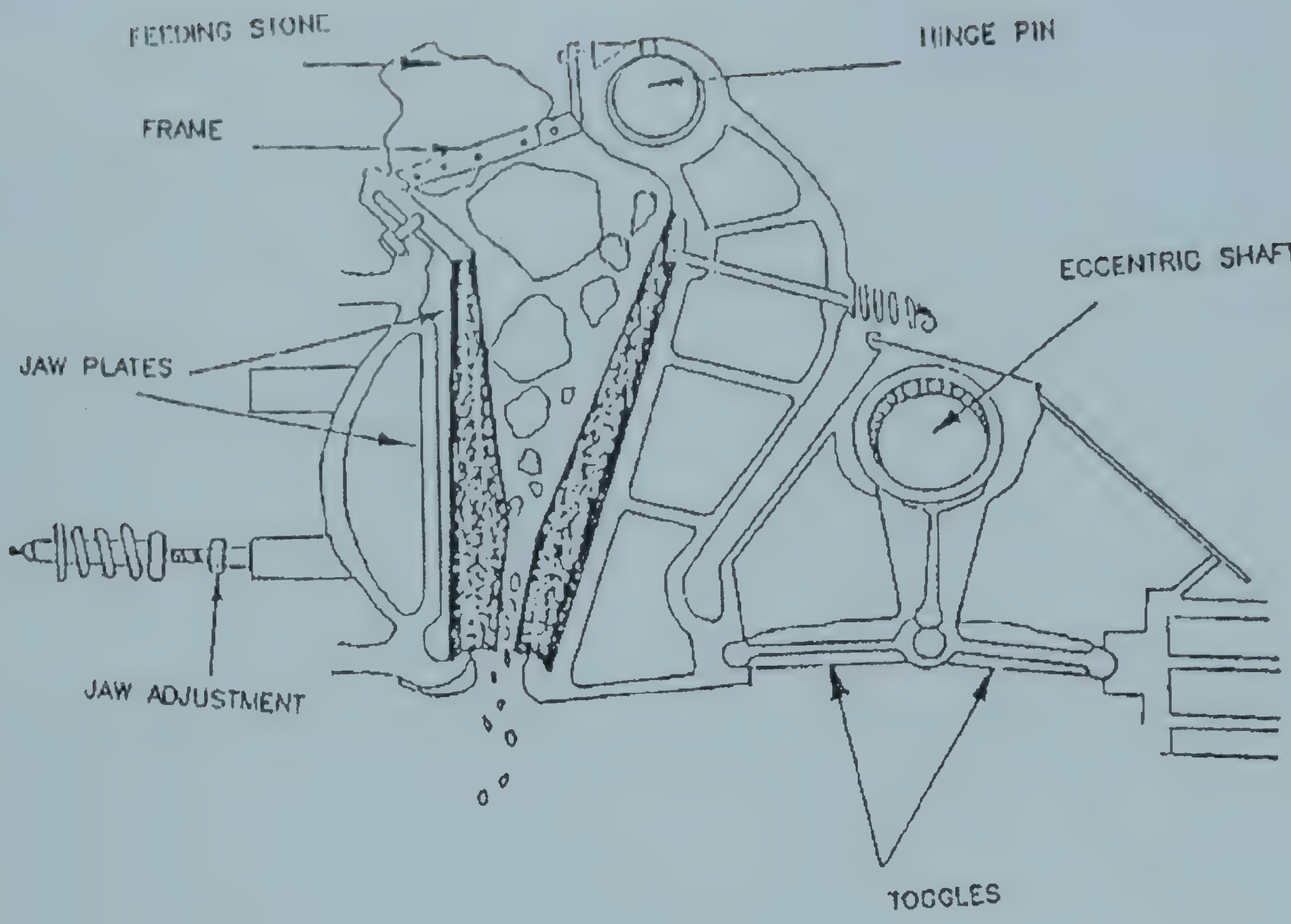
A vertical shaft impactor (Fig. 3.4) comprises a horizontal table or rotor that revolves about the vertical axis of the drive shaft. The crushed rock fed into the centre of the rotor is ejected at high speeds and breaks by impact upon the hardened alloy anvils surrounding the rotor and by inter-particulate collision.

The advantages are (i) cubical product shape and (ii) overcoming the problem of wear while crushing abrasive rocks.

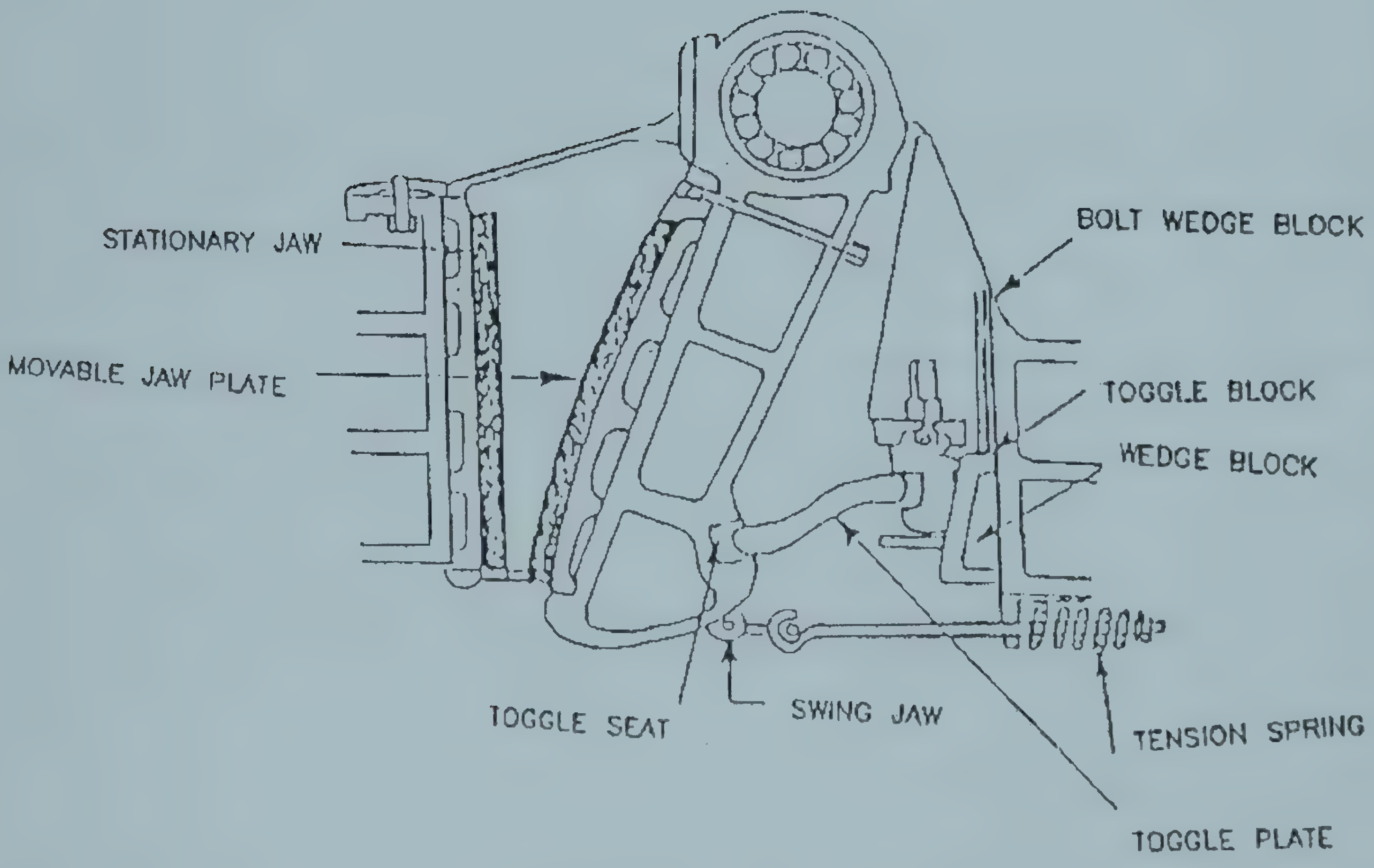
B. Secondary and Tertiary Types

(1) Cone Crushers : Eventhough the jaw and gyratory types of crushers may be adapted to secondary and tertiary crushing, it is because of the greater capacity of the cone crusher that cone crushers are very commonly used for secondary and tertiary crushing.

The Cone Crusher is a development of the gyratory crusher. It consists of a gyratory upright conical crushing member,


FEEDING STONE
HINGE PIN
FRAME
ECCENTRIC SHAFT
JAW PLATES
JAW ADJUSTMENT
TOGGLES

(a) Double Toggle Jaw Crusher


STATIONARY JAW
BOLT WEDGE BLOCK
MOVABLE JAW PLATE
TOGGLE BLOCK
WEDGE BLOCK
TOGGLE SEAT
SWING JAW
TENSION SPRING
TOGGLE PLATE

(b) Single Toggle Jaw Crushers

Fig. 3.1. Jaw Crushers

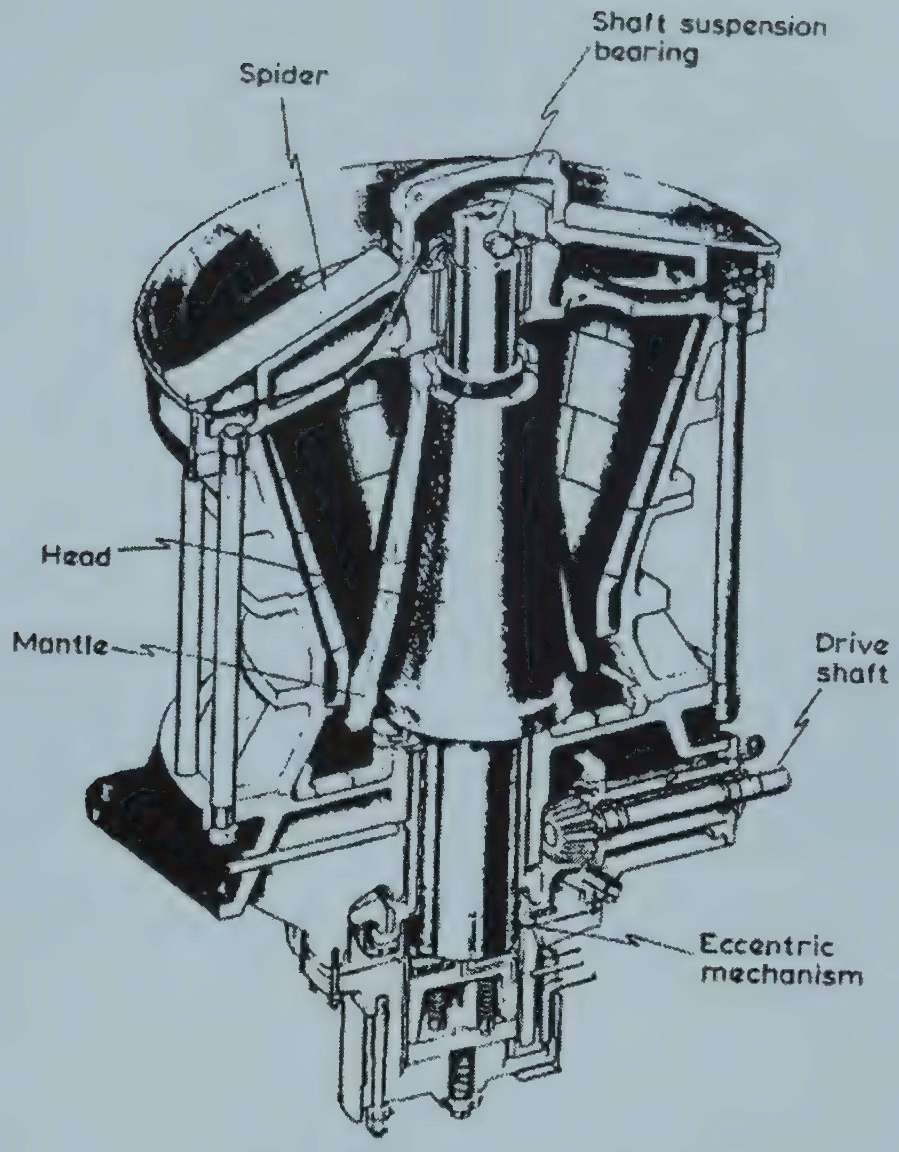

Shaft suspension bearing
Spider
Head
Mantle
Drive shaft
Eccentric mechanism

Fig. 3.2. Gyratory Crusher

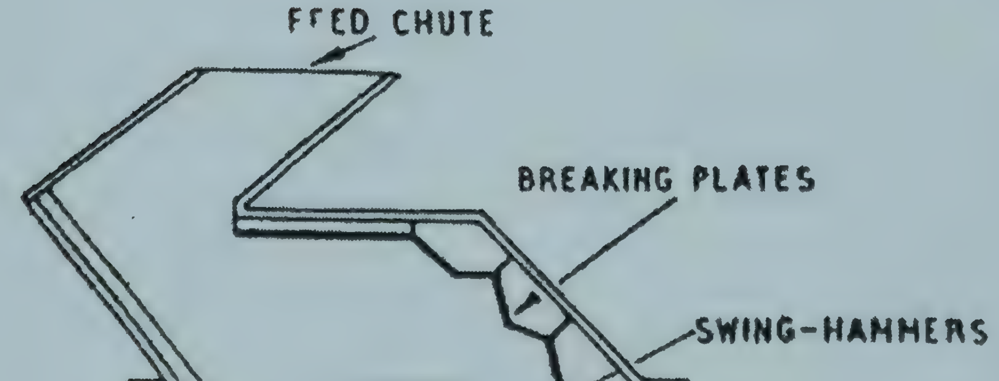

FEED CHUTE
BREAKING PLATES
SWING-HAMMERS
HINGE
ROTOR DISCS
CASING

Fig. 3.3. Swing Hammer Mill (Impactor)

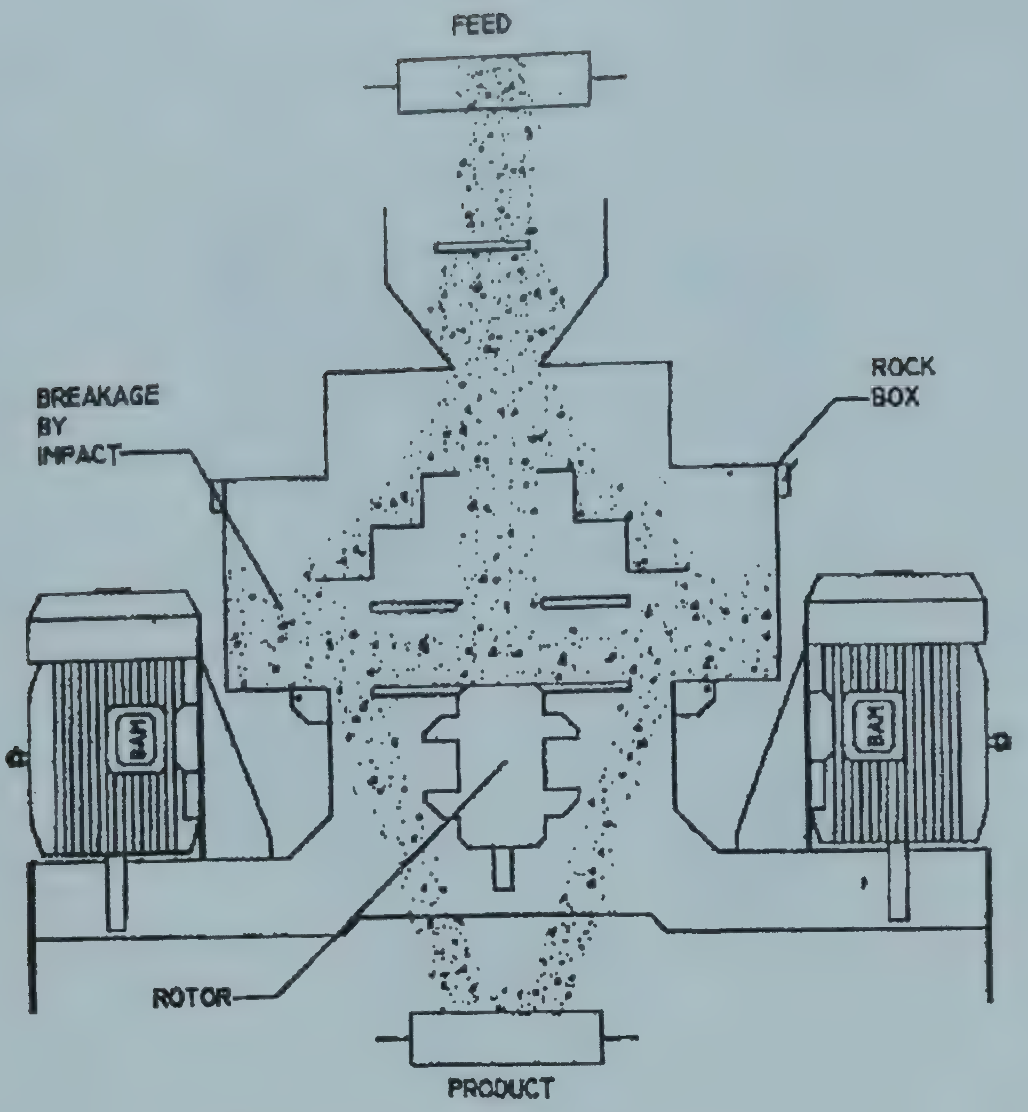
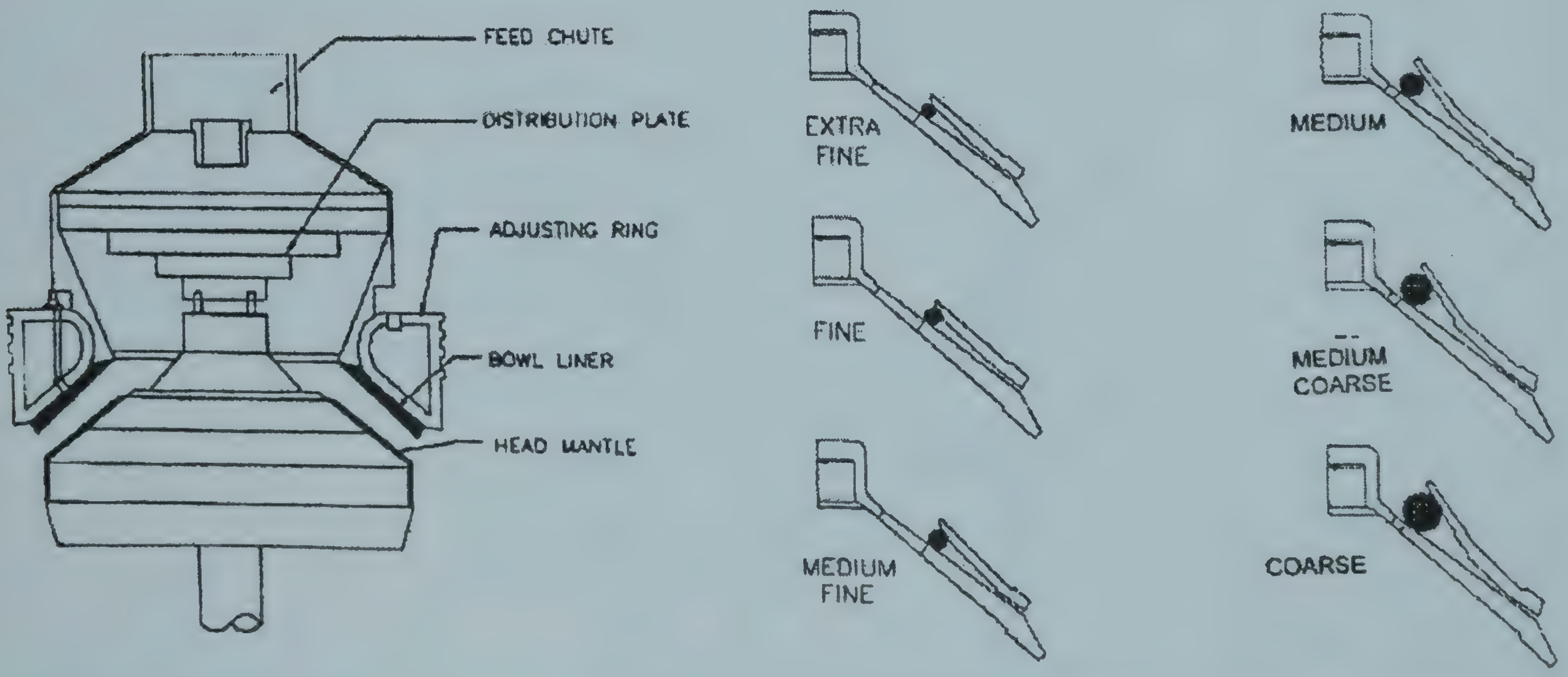

FEED
ROCK BOX
BREAKAGE BY IMPACT
BJM
BJM
ROTOR
PRODUCT

Fig. 3.4. Vertical Shaft Impactor

the head lined with mantle within a conical crushing chamber lined with/wearing metal. Cone crushers are designated by the diameter of the head. A typical cone crusher is shown in Fig. 3.5.


FEED CHUTE
DISTRIBUTION PLATE
ADJUSTING RING
BOWL LINER
HEAD MANTLE
EXTRA FINE
FINE
MEDIUM FINE
MEDIUM
MEDIUM COARSE
COARSE

(a) Typical Cross-Section of Cone Crusher

(b) Types of Mouth Openings in Cone Crusher

Fig. 3.5. Cone Crusher

The main difference from gyratory type is that the crushing chamber is also in the form of an upright, truncated cone and the gyrating cone (45° angle) is supported entirely from beneath by the eccentric bush assembly. Also, the eccentric shaft rotates very much more rapidly (more than 200 rpm) than that of gyratory crusher. Thus, there is an improved energy utilisation and improvement in the shape of aggregate. In order to ensure good cubical shape, low reduction ratios have to be used and also the crushing chamber should always be full of material, known as 'choke feed'

The secondary cone crusher has a steeply inclined (sometimes stepped) crushing chamber formed by concave and a flatter, less steeply inclined conical crushing member. Reduction ratio achieved varies from 4:1 to 8:1.

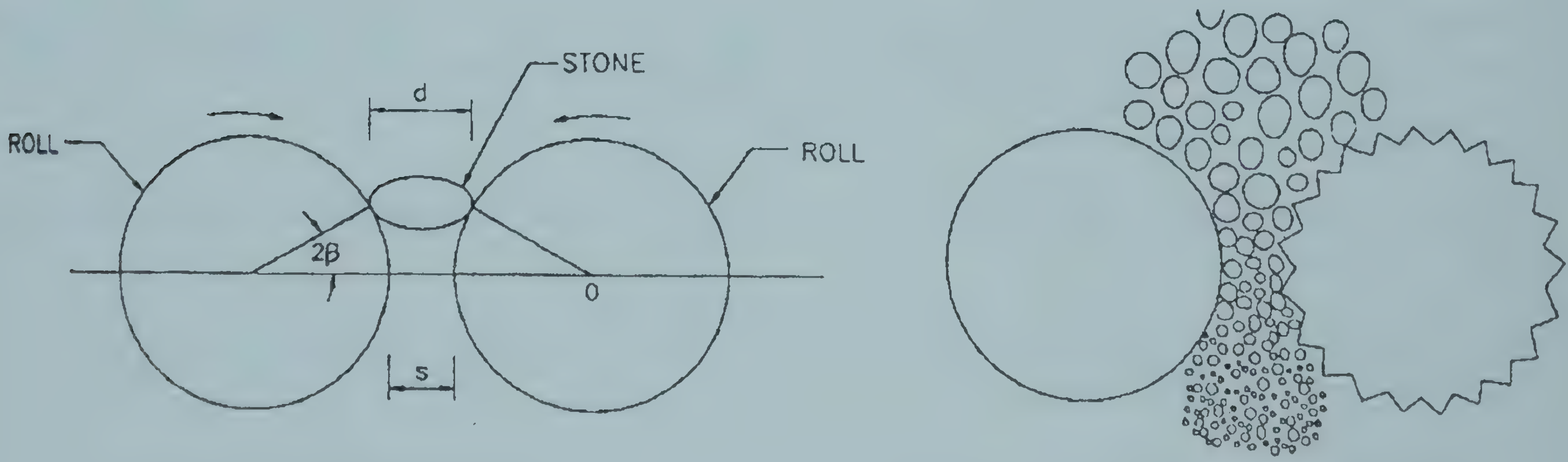
The tertiary, short-head-cone-chamber has both crushing chamber and cone steeply inclined to promote the gravitational flow of more finely sized material.

(2) **Rolls Crushers :** Essentially, a rolls crusher comprises two contrarotating crushing rolls. The reduction ratio is generally limited to 3:1.

Their use was common before the development of cone crushers. They suffer from the following two disadvantages:

- low-capacity
- wear of the roll surface when crushing abrasive rock

Rolls crusher may still find application within small capacity operations in confined spaces where simple construction and low headroom requirement arc advantages or for processing very soft rocks (like, high purity limestones). In the modem versions the rolls are' provided with hardened alloy steel teeth. Rock is broken by a combination of compression, tension and shear. A typical rolls crusher is shown in Fig. 3.6.



(a) Principal of Roll Crusher

(b) Double Roll Crusher

Fig. 3.6. Rolls Crusher

3.3 Evaluation of Aggregates

3.3.1. General : Aggregates produced from rocks or naturally occurring sources must be tested for their suitability for incorporation in bituminous mixes. They are normally tested for physical, mechanical, chemical and petrographic characteristics. Physical properties of the aggregates, like specific gravity, density, voids and absorption are necessary for the design of bituminous paving mixtures. Mechanical properties, like resistance to impact and abrasion, and compressive strength, are checked to assess the hardness and toughness of these aggregates. Aggregates are also subjected to a chemical test known as soundness test wherein their weathering and durability behaviour under freezing and thawing conditions is assessed. Petrography is the science dealing with the origin and composition of rocks and it is useful for evaluating the durability of aggregates. Porosity, chemical composition of the aggregates and their degree of weathering, together with the environmental conditions to which they will be exposed, are primary factors which affect the durability of aggregates.

While some of the prevailing Bureau of Indian Standard Specifications for concrete aggregates may be applied to the selection of aggregates used in bituminous works, an additional set of specifications has yet to be evolved by BIS specifically for selecting aggregates for use in bituminous works.

3.3.2. Sampling of aggregates : Aggregates sampled should be representative of the batch or stockpile to be tested. For collection of samples, see para 10.5.2.2. The size of samples to be collected for each test has been specified in the relevant method of test given in IS:2386 (Part I) to IS:2386 (Part VIII). The repeatability and reproducibility of test results depend primarily on the sampling. A laboratory sample is obtained from a bulk sample collected, either in a number of increments or in one go, from a batch or a stockpile. Samples are normally collected using a sampler which is in the form of metallic tube or a scoop whose opening is 3 times the maximum aggregate size. Sampling of aggregates is sometimes done at various production sources in order to avoid the segregation which occurs in stockpiles. Some of the sampling procedures followed are:

1. Sampling from stationary conveyor belt
2. Sampling at belt and chute discharge points
3. Sampling from stockpiles
4. Sampling from railway wagons, transporting dumpers/trucks, etc.

A sample collected for testing purposes has to be reduced in size to prepare laboratory samples. The aggregates are quartered either manually or by using riffle boxes. The riffle box is described in para 10.5.2.3.

3.3.3. Testing of Aggregates

3.3.3.1. Common tests for aggregates : The tests usually conducted on aggregates for bituminous work are as below: -

SI. No.	Name of Test	Test Method
1.	Presence of deleterious materials	IS : 2386 - Part — 2 IS : 2720 - Part — 37
2.	Specific gravity, water absorption and bulk density	IS : 2386 - Part — 3
3.	Particle size distribution Plasticity index	IS : 2386 - Part — 1
4.	Flakiness and elongation	IS : 2720 - Part — 5
5.	Mechanical properties including aggregate crushing value, impact value, abrasion value and polished stone value	IS : 2386 - Part — 1
6.	Soundness test using either sodium sulphate or magnesium sulphate	IS : 2386 - Part - 4 BS : 812 - Part - 114
7.	Bitumen coating and stripping test IS: 6241	IS : 2386 - Part - 5 IS : 6241
8.	Water sensitivity test	AASHTO T 283

Permissible limits within which the test values, for the various laboratory tests mentioned above should lie have been indicated in the requirements for each type of bituminous construction covered in appropriate sections of this Manual.

3.3.3.2. Deleterious materials : Aggregates containing foreign or deleterious materials are undesirable for bituminous work. Objectionable materials are vegetable matter, shale, soft particles, clay lumps, and clay-clad coarse aggregates. The sand-equivalent test is a suitable method for determining the proportion of silt and/or clay size material in fine aggregate. IS:2720 (Part 37) gives the details of the determination of sand equivalent value of fine aggregates (Fig. 3.7).

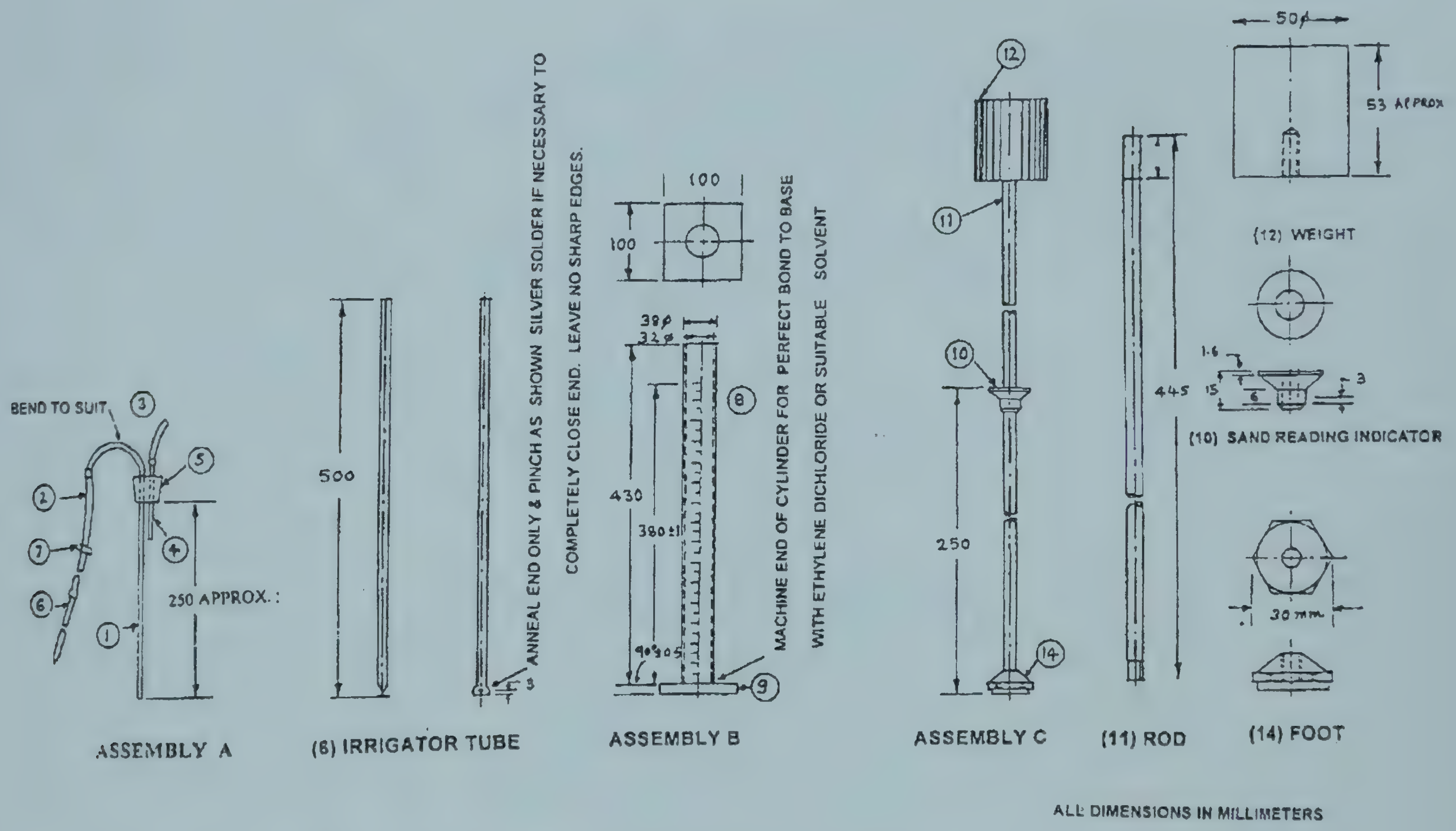

BEND TO SUIT
③
②
⑤
⑦
④
⑥
250 APPROX.
①
ASSEMBLY A
500
(6) IRRIGATOR TUBE
ANNEAL END ONLY & PINCH AS SHOWN SILVER SOLDER IF NECESSARY TO
COMPLETELY CLOSE END. LEAVE NO SHARP EDGES.
3
100
100
38ϕ
32ϕ
⑧
430
380±1
90°±0.5
⑨
ASSEMBLY B
MACHINE END OF CYLINDER FOR PERFECT BOND TO BASE
WITH ETHYLENE DICHLORIDE OR SUITABLE SOLVENT
⑫
⑪
⑩
250
⑭
ASSEMBLY C
445
(11) ROD
50ϕ
53 APPROX
(12) WEIGHT
1.6
15
6
3
(10) SAND READING INDICATOR
30 mm
(14) FOOT
ALL DIMENSIONS IN MILLIMETERS

Fig. 3.7. Sand Equivalent Test Apparatus for Fine Aggregates [IS:2720, (Part 37)]

3.3.3.3. Specific gravity, water absorption and bulk density of aggregates : Determination of the specific gravity of aggregates (both coarse and fine aggregates) is necessary for the purpose of design of bituminous mixes. Normally, both bulk and apparent specific gravities of the aggregate particles are determined. Apparent specific gravity considers the volume as being the volume of the aggregate particles not including the volume of any pores or capillaries that become filled with water after a 24-hour soaking. Bulk specific gravity considers the overall volume of the aggregate particles including the pores that become filled with water after a 24-hour soaking. Water absorption of aggregate particles indicates the possible bitumen absorption by the aggregates. Normally, aggregates having water absorption of more than 2 per cent are not considered suitable for bituminous work. The bulk density of total loose aggregates is helpful in calculating the capacity requirements of trucks, etc., for transporting the aggregates. The test procedures are covered by IS:2386 (Part-3).

3.3.3.4. Size and gradation of aggregates : Maximum size of an aggregate is the mesh size of the smallest sieve through which 100 per cent of the material will pass. Nominal maximum size is the largest specified sieve size upon which any of the aggregate material is retained.

Gradation analysis of both coarse and fine aggregates are carried out by sieving, using standard set of sieves. IS:2386 (Part I) defines the required procedure.

Dry sieve analysis is generally suitable for the testing of graded coarse aggregates. However, when the aggregate contains fine dust or clay sticking to the coarser aggregate particles, a wet/washed sieve analysis should be carried out. Fig. 3.8 shows the use of sieves for determining the particle size distribution.

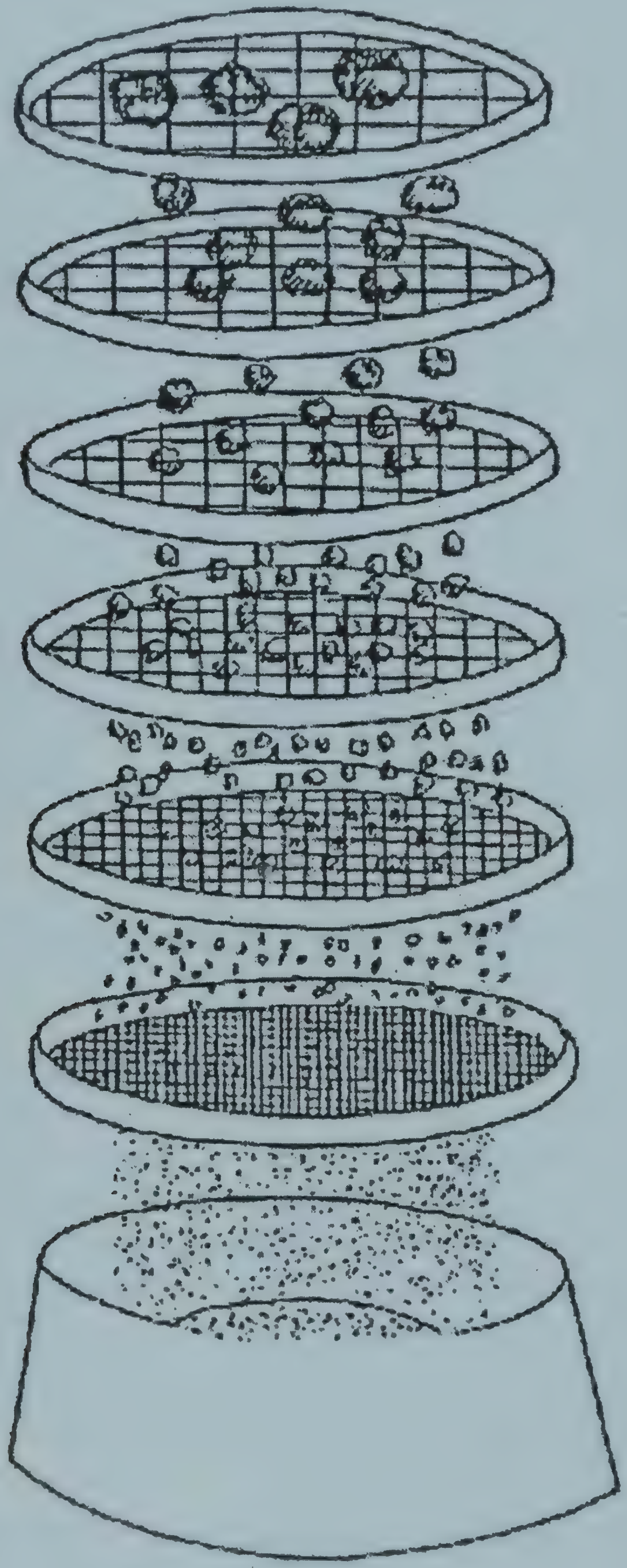
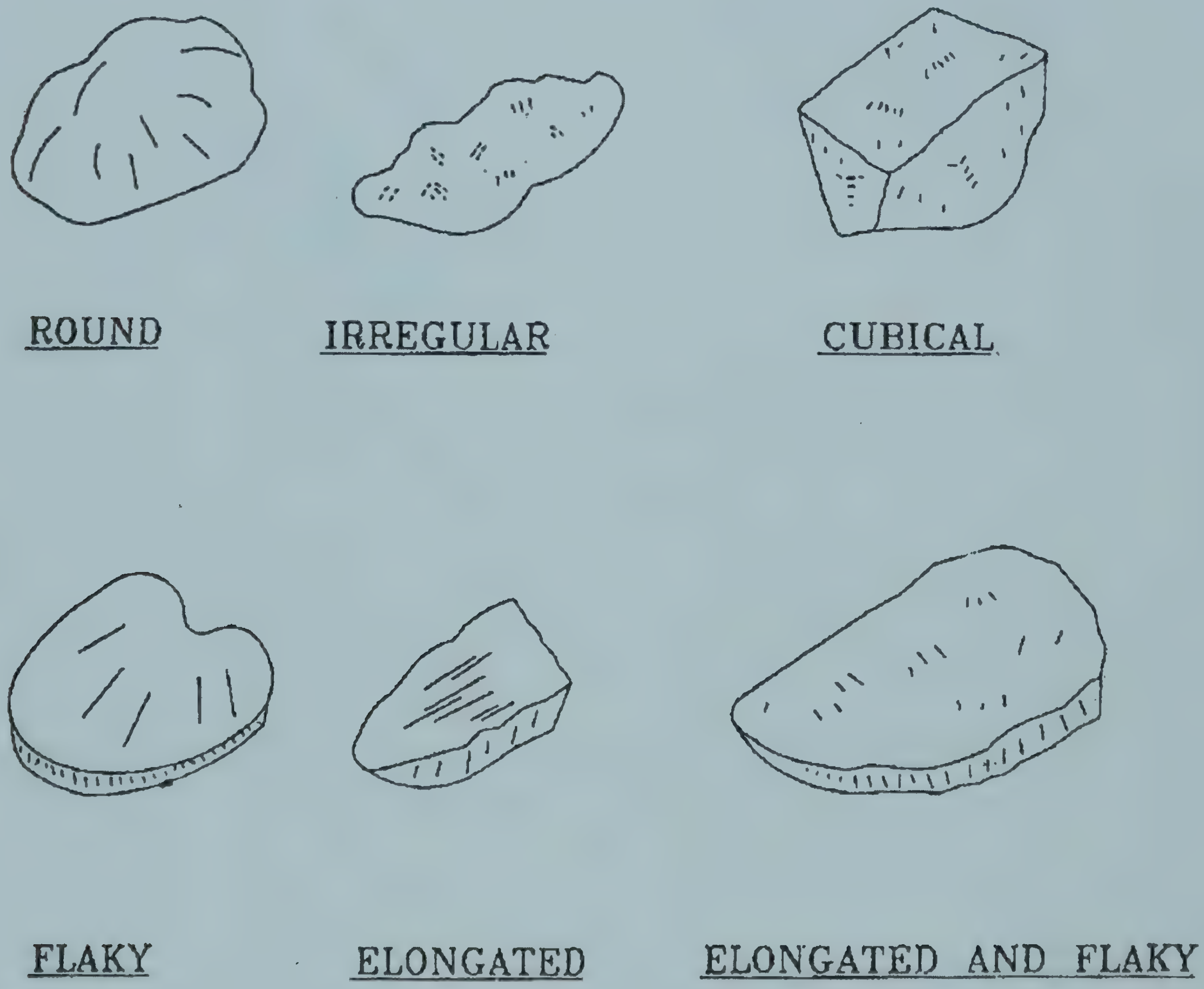


Fig. 3.8. Sieves used to Analyse the Particle Size Distribution

Maximum size and grading of aggregates are invariably controlled by the specifications, which describe the distribution of particle sizes to be used for a, particular work.

3.3.3.5. Flakiness and elongation tests : These tests are conducted on coarse aggregates to assess the shape of aggregates. Aggregates which are flaky or elongated are detrimental to the higher workability and stability of mixes. They are not conducive to good interlocking and hence the mixes with an excess of such particles are difficult to compact to the required degree. Different shapes of aggregate particles are illustrated in Fig. 3.9.


ROUND IRREGULAR CUBICAL

FLAKY ELONGATED ELONGATED AND FLAKY

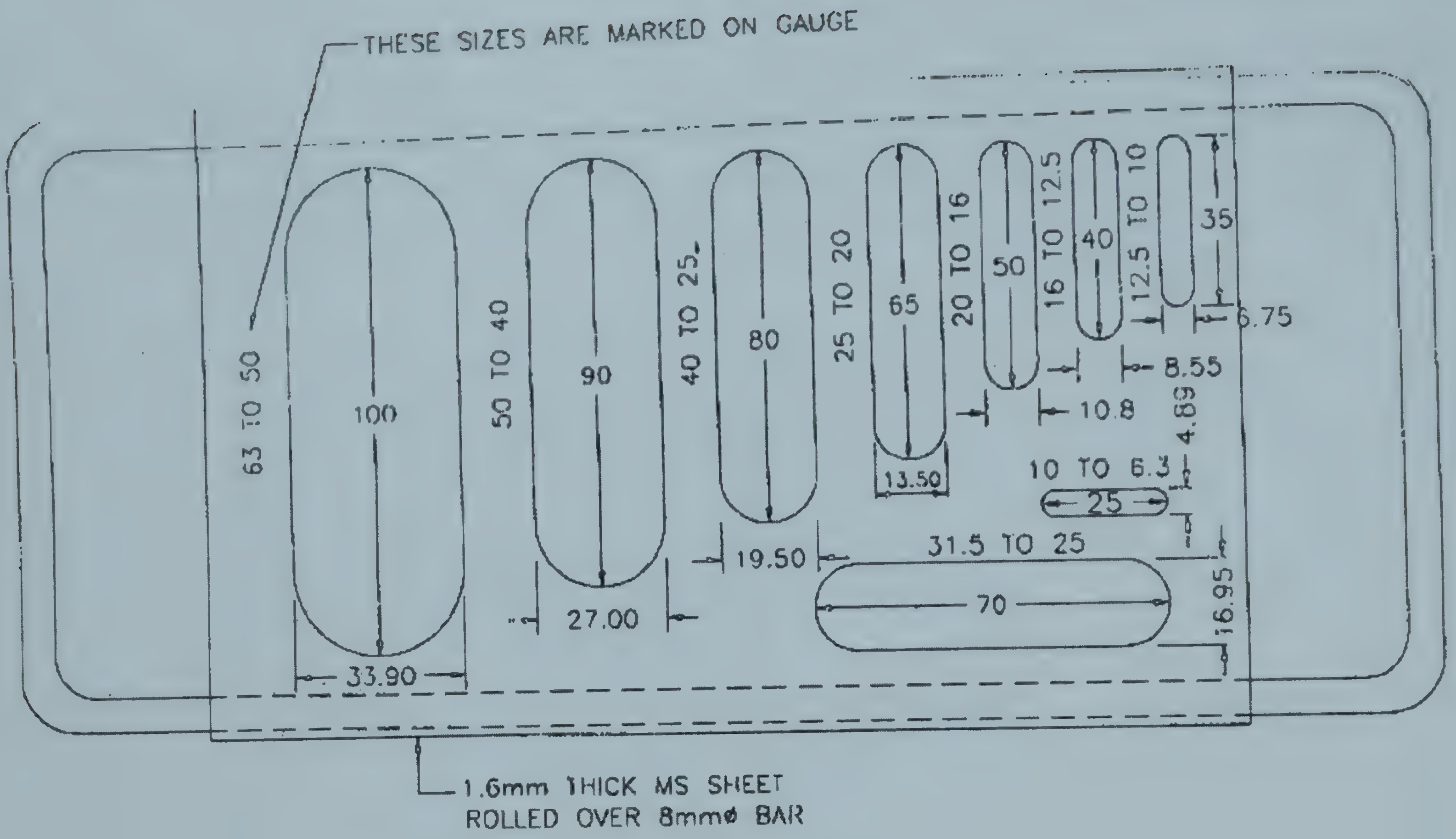
Fig. 3.9. Shapes of Aggregate Particles

The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 of their mean size. It is determined according to the procedure laid down in IS:2386 (Part I).

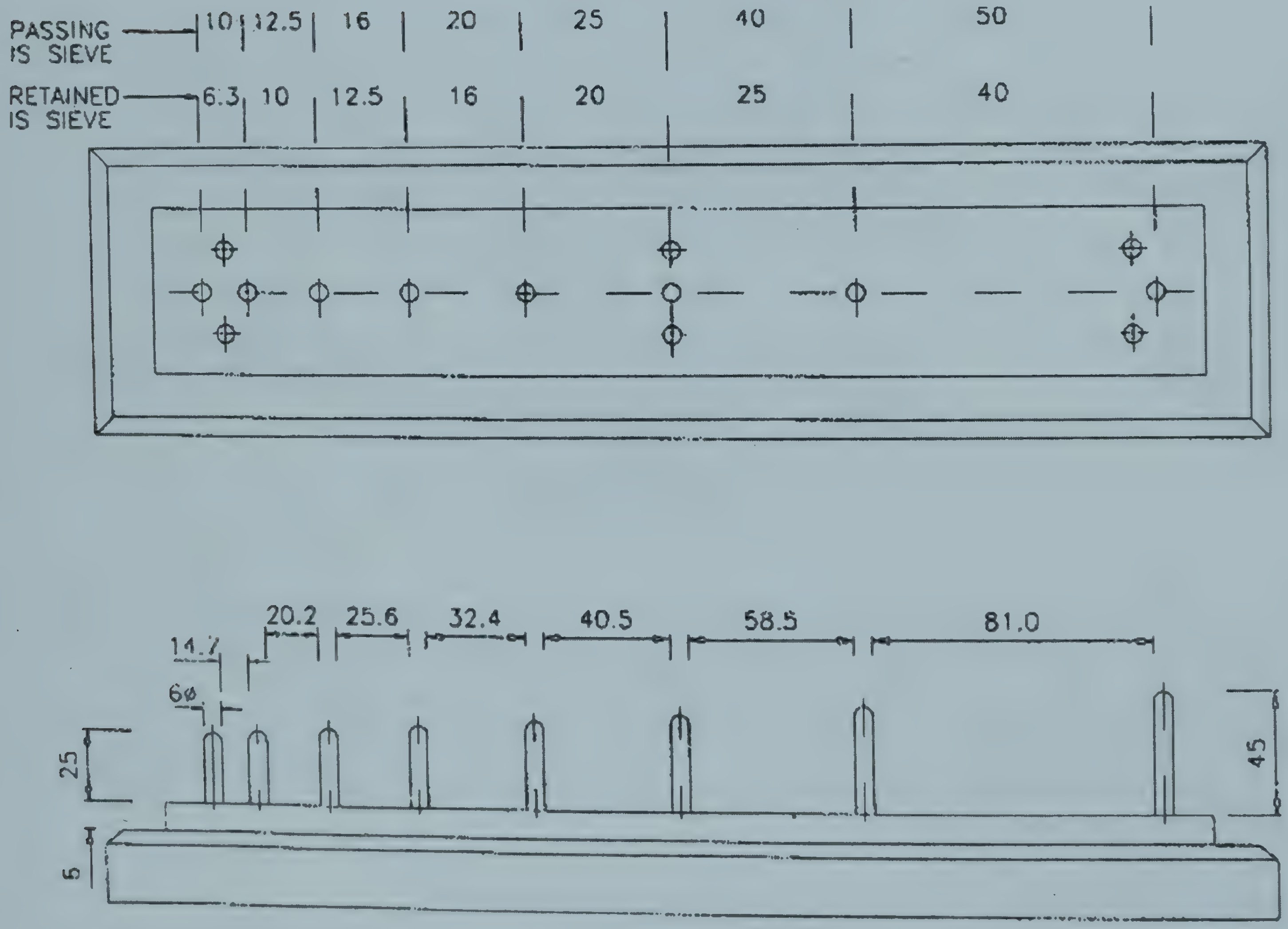
The elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than one and four-fifths times their mean dimension. This test is not applicable to aggregates smaller than 6.3 mm. The test is covered by IS:2386 (Part I).

The standard flakiness and elongation gauges are shown in Fig. 3.10.

The combined value of flakiness and elongation indices, recommended by the Ministry's Specifications tes for many of the bituminous materials for roadworks, is 30.


THESE SIZES ARE MARKED ON GAUGE
63 TO 50
100
33.90
50 TO 40
90
27.00
40 TO 25
80
19.50
25 TO 20
65
13.50
20 TO 16
50
10.8
16 TO 12.5
40
8.55
12.5 TO 10
35
6.75
4.89
10 TO 6.3
25
31.5 TO 25
70
16.95
1.6mm THICK MS SHEET
ROLLED OVER 8mmø BAR

(a) Flakiness Gauge


PASSING IS SIEVE
10
12.5
16
20
25
40
50
RETAINED IS SIEVE
6.3
10
12.5
16
20
25
40
14.7
20.2
25.6
32.4
40.5
58.5
81.0
6ø
25
5
45

(b) Elongation Gauge

Fig. 3.10. (a) Flakiness Gauge, (b) Elongation Gauge

3.3.3.6. Mechanical properties and polishing characteristics : The tests covered under mechanical properties of aggregates are crushing value, impact value, abrasion value, and polished stone value. IS:2386 (Part-IV) describes the testing methods for evaluating mechanical properties. These tests evaluate the ability of the aggregates to withstand the stresses induced by moving vehicles in the form of wear and tear, impact and crushing. Shown in Figs. 3.11 and 3.12 are schematic diagrams of Aggregate Impact Testing Equipment and Los Angeles Abrasion Testing Equipment.

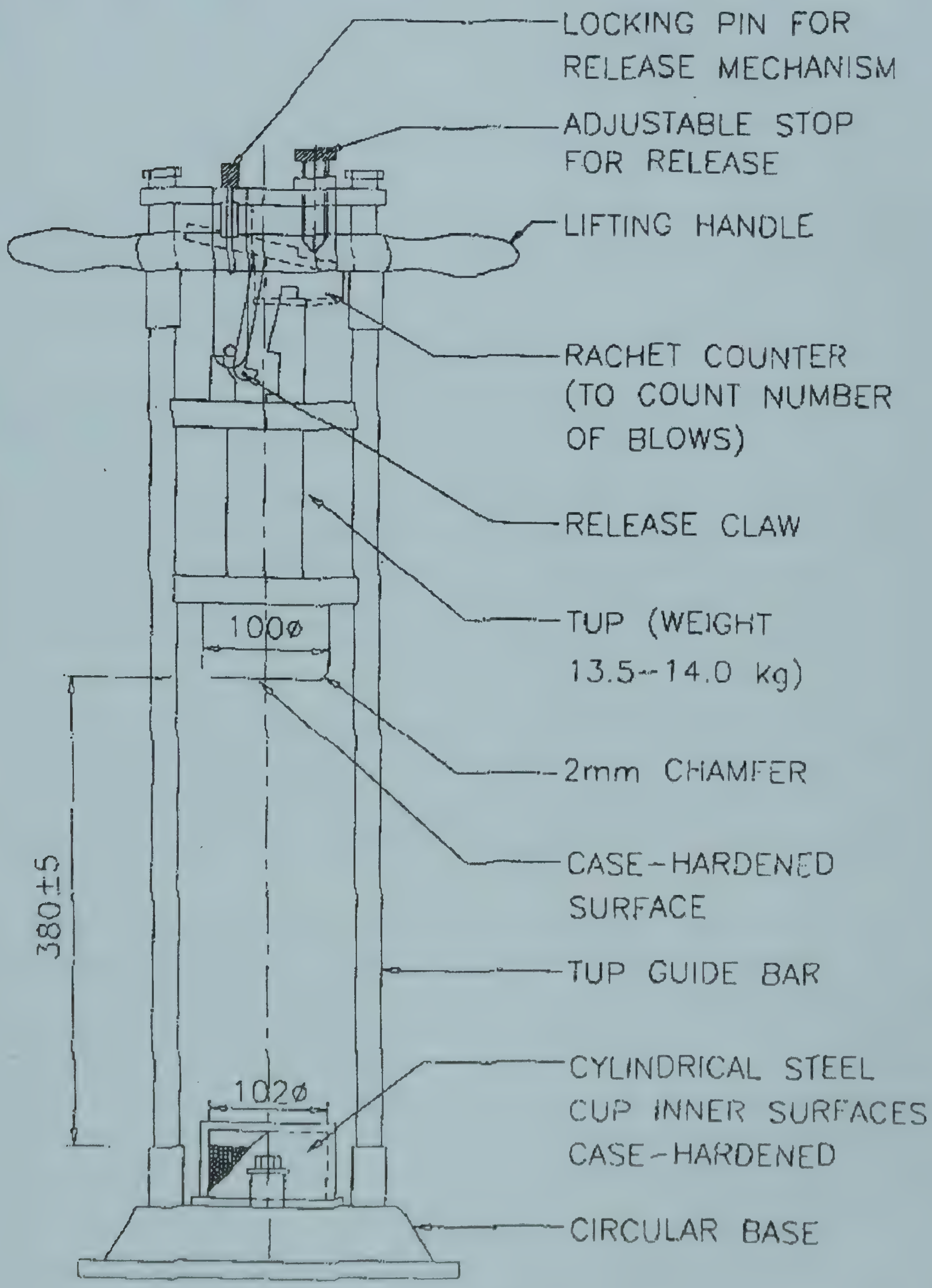

LOCKING PIN FOR RELEASE MECHANISM
ADJUSTABLE STOP FOR RELEASE
LIFTING HANDLE
RACHET COUNTER (TO COUNT NUMBER OF BLOWS)
RELEASE CLAW
TUP (WEIGHT 13.5--14.0 kg)
100ø
2mm CHAMFER
CASE-HARDENED SURFACE
380±5
TUP GUIDE BAR
102ø
CYLINDRICAL STEEL CUP INNER SURFACES CASE-HARDENED
CIRCULAR BASE

Fig. 3.11. Aggregate Impact Test Machine

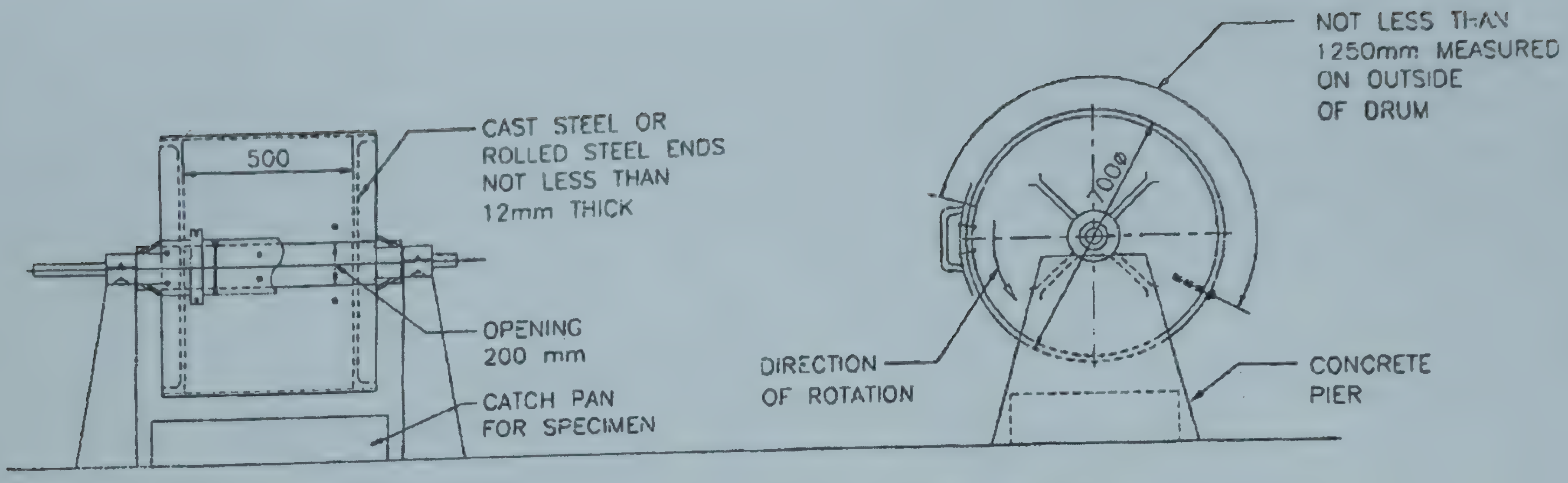

500
CAST STEEL OR ROLLED STEEL ENDS NOT LESS THAN 12mm THICK
OPENING 200 mm
CATCH PAN FOR SPECIMEN
DIRECTION OF ROTATION
700φ
NOT LESS THAN 1250mm MEASURED ON OUTSIDE OF DRUM
CONCRETE PIER

Fig. 3.12. Los Angeles Abrasion Testing Machine

Aggregates used in bituminous surface mixes are subject to polishing by vehicle tyres. The test in BS:812 (Part-114) is used for determining the polished-stone value of aggregates. The test is conducted in two parts:

(a) Samples of stones are subjected to an accelerated polishing action in a specially designed machine. The aggregate samples are fixed on a moving cylindrical surface which is subjected to abrasion.

(b) The state of polish reached by each sample is then measured by means of a suitable friction tester developed by Road Research Laboratory, U.K. and the result is expressed as the 'Polished Stone Value' (PSV).

3.3.3.7. Soundness test : This is a durability and weathering test conducted on aggregates. Porous aggregates ~subjected to freszing and thawing are likely to disintegrate prematurely. To ascertain the durability of such aggregates, they are subjected to an accelerated soundness test specified in IS:2386 (Part-5). Aggregates of a specified size are subjected to cycles of alternate wetting, in a saturated solution of either sodium sulphate or magnesium sulphate at a certain temperature, and then drying in air. After five cycles, the loss in weight of the aggregates by fragmentation is determined by sieving out all undersize particles and weighing.

3.3.3.8. Stripping and water sensitivity tests : Stripping is a phenomenon in which a film of bitumen, coating an aggregate particle, becomes displaced by water. It occurs with some aggregate types and some bitumens, in the presence of water and (normally) trafficking. Aggregates of siliceous origin, like, quartzite and granites have been identified as being prone to stripping. Existing tests do not adequately characterise the combined effects of water with the dynamic effects of trafficking.

There are a number of laboratory tests in use, which evaluate the resistance of an aggregate to bitumen film stripping in the presence of water. In the static immersion tests clean, dry, single-sized aggregates are coated with a specified percentage of bitumen binder and, after being allowed to stand at room temperature for a specified period, the sample is immersed in distilled water. At the end of the immersion period, the aggregate particles are visually examined for signs of stripping and the residual coated area is estimated. Such a test has been standardised in India as per IS:6241 and adopting this test procedure, a maximum stripping value to the extent of 25 per cent was earlier considered acceptable. Mechanical immersion tests have also been carried out involving measurement of the change in the mechanical properties of compacted specimens of bituminous mixtures after extended periods of immersion in water, e.g., ASTM D1075.

In preference to the static and mechanical immersion tests, the Ministry's Specifications recommend the use of Water Sensitivity Test as per AASHTO T283. In this test, Marshall specimens are prepared at the desired bitumen content and density for each set of mix conditions. Each set of these Marshall specimens is divided into subsets. One subset is tested in dry condition for indirect tensile strength and the other is subjected to vacuum saturation followed by a freeze and warm water soaking cycle and then tested for indirect tensile strength. Retained indirect tensile strength properties are compared for the two subsets: dry and vacuum saturated. For climatic conditions prevailing in most parts of India, the method provides for exercising an option for eliminating the freeze-thaw cycle. Such an option makes it possible to evaluate the retained indirect tensile strength on the two subsets of "dry" and "saturated" conditions only. A minimum retained tensile strength of 80 per cent is normally specified.

The results of AASHTO T283 test can be effectively used to predict the long-term stripping susceptibility of the bituminous mixtures and evaluating anti-stripping additives.

CHAPTER 4

BITUMINOUS PAVEMENT LAYERS

4.1. Introduction

The two broad categories of bituminous pavement construction are: -

- Sprayed or penetration Layer Systems
- Pre-Mixed Aggregate and Bitumen Mixtures

Sprayed or penetration layer systems are provided by placing bitumen and aggregate (where appropriate) in separate courses or layers, Aggregate and bitumen are not mixed prior to laying and compaction.

In pre-mixed aggregate and bitumen mixtures, the aggregates and bituminous binder are mixed before hand in a suitable plant before laying and compaction at the site .

4.2. Sprayed or Penetration Layer Systems

1. Interface Treatments

   For all types of bituminous construction, it is necessary that a bituminous layer is provided with an adequate bond with the underlying course. Also, Where appropriate, the underlying course should be rendered impermeable to bitumen to avoid loss of bitukmen fron the applied bituminous course. The interface treatments include the following:-

   - Prime Coat
   - Tack coat
2. Liquid Seal Coat
3. Bituminous Penetration Macadam
4. Built-up Spray Grout
5. Surface Dressing
6. Fog Spray

For each of the above-mentioned bituminous constructions, a brief description of the type of construction, its use/purpose and detailed information on the materials (both aggregates and bituminous binder) involved are given. The detailed in formation of equipment and construction procedure are, however, given in Chapters 6 and 8 respectively.

4.2.1. Prime coat (Clause 502 of Ministry, s Specifications)

4..2.1.2. Description : Prime Coat is an application of a low viscosity bitumen emulsion to an untreated absorbent base in preparation for a bituminous course. Good penetration of the prime cot (upto 5 mm) into the base is desirable, which is why low viscosity primer is preferred.

4.2.1.2. Use : The purpose of priming is:-

1. To plug the capillary voids.
2. To coat and bond loose materials on the surface.
3. To harden or toughen the surface.
4. To promote adhesion between the layer being primed and the superimposed bituminous layer.

4.2.1.3. Materials : The binder ordinarily used for priming should be a bitumen emulsion complying with the requirements of IS: 8887 the use of cutback bitumen should be restricted to sites at sub-zero temperatures or for emergency operations.

The selection of the primer will depend on the porosity of the surface to be primed. The recommended ranges of viscosity for primer for different types of surfaces are given below:-

Type The Surface	Kinematic Viscosity of Primer at 60 c (CSt)	Rate of Spray (Kg/m^2)
• low porosity (e.g. WBM/WMM)	30-60	0.6 to 0.9
• Medium porosity (e.g. Soil Cement)	70-140	0.9 to 1.2
• High Porosity (e.g. Gravel Base)	250-500	1.2 to1.5

The grades of emulsions normally used are: SS-lh, CSS-l or CSS-1h. Where cutback bitumen has to be used, the grades MC-30 and MC-70 May be used for low porosity and medium porosity surfaces respectively, while a more viscous grade of MC-250 may be used for loosely bonded, open-textured surfaces.

The correct quantity of primer will the maximum amount that can be absorbed by the surface without causing run-off of excessive primer (sometimes referred to as "finger") to form at the lower edges of the primed area. it will, therefore, be a matter of trial and judgement, to be decided by the supervising engineer at the site.

The area to be primed must be cleared of all excess loose material and, while the prime will act to bind small quantities of loose material to the road surface. it cannot be used as a cure for a poor finish to the surface of a granular base layer.

For environmental reasons. emulsion primes are to be used, in preference to cutbacks, as the cuting agents therein, after dispersion, can be harmful pollutants, whereas. the water used in the manufacture of emulsions is not subsequently harmful to the environment.

In case the bituminous primer has not been completely absorbed by the base within 24 hours it is good practice to apply a light sand dusting to blot up the excess primer material.

4.2.2. Tack coat (Clause 503 of Ministry's Specifications)

4.2.2.1. Description : A tack coat is an application of low viscosity liquid bituminous binder to an existing bituminous surface prior to the superimposition of a bituminous Mix.

4.2.2.2. Use : it is used to ensure a bond between the new construction and the old surface.

When an additional course is placed within a couple of days on a freshly laid bituminous layer that has not been used by traffic or on an old bitumen-rich surface in warm weather, the tack coat may be dispensed with.

4.2.2.3. Binder : The binder used for tack coat should be bitumen emulsion complying with IS:8887, the preferred grades being SS-1, SS-1h, CSS-1 and CSS-1h. The use of cutback bitumen as per IS:217 should be restricted only for sites at sub-zero temperatures or for emergency applications.

4.2.2.4. Quantities : The Quantity of binder should be carefully chosen, the goal being a very thin but uniform film of bitumen. Too much of tack coat may lead to fattening of the surface and slippage between the two pavement courses. the binder acting as a lubricant rather than as a bonding medium.

The rate of application should be as given in the Table 4.1

Table 4.1. Rate of Application of Track Coat

Type of Surface	Quantity of Liquid Bituminous Material in kg/m^2
Normal Bituminous Surfaces	0.20 to 0.25
Dry And Hungry Bituminous Surfaces	0.25 to 0.30
Granular Surfaces Treated with Primer	0.25 to 0.30
Non-Bituminous Surfaces:	
Granular Base (Not Primed)	0.35 to 0.40
Cement concrete Pavement	0.30 to 0.35

4.2.3 Liquid seal coat (Clause 513 of Ministry' s Specifications

4.2.3.1. Description: Liquid seal coat comprises of an application of a layer of bituminous binder over an existing bituminous surface, followed by a cover of stone chippings.

4.2.3.2. Use : The application of liquid seal seal over an existing bituminous surface is for the purpose of sealing the voids in the bituminous surface. It is an alternative to a premixed seal coat.

4.2.3.3. Materials

a) Stone chippings should consist of angular fragments of clean, hard, tough and durable rock of uniform quality throughout. They should be fee of soft of disintegrated stone, organic or other deleterious matter. Stone chippings should be of 6.7 mm size defined as 100 per cent passing through 11.2 mm sieve and retained on 2.36 mm sieve. Stone chippings should satisfy the physical requirements at table 4.3, except that the upper limit for water absorption should be 1 per cent.

(b) Binder should be bitumen of a suitable grade appropriate to the region, traffic, rainfall and other environmental conditions or other approved cutback or emulsion satisfying the requirements of IS:73; 217; 454 or 8887 as applicable. Further guidance in this regard may be taken from para 2.4.

4.2.3.4. Quantities of Materials : The quantity used for spreading the stone chippings should be 0.09 m^3 per10 m^2 area. The quantity of bitumen should be 9.8 kg per 10 m^2

4.2.4. Bituminous Penetration Macadam (Clause 505 of Ministry's Specifications)

4.2.4.1. Description : A penetration macadam is a compacted layer of coarse aggregates into which bituminous binder is introduced. The binder penetrates into the layer through the voids and binds the stone aggregates. A layer of Smaller Aggregates, called key aggregates, is spread on the surface and rolled so as to fill in the surface voids in the coarse aggregate layer. A seal coat is provided to make the surface more impervious to water.

4.2.4.2. Use : The penetration macadam specification was in vogue ad a vase material for pavement construction many decades ago. It is not advocated for use in heavily trafficked situations, for which the more efficient coated macadam is preferred. In India, it is still used in remote areas where it is difficult to transport mixing and laying equipment. It can also be used as a temorary emergency material to repair a pavement damaged by rains and floods.

4.2.4.3. Materials

(1) Aggregates

The coarse aggregates form the matrix, which gives the inherent strength due to interlocking. and friction between the particles. The Key aggregates, which are smaller in size. penetrate into the surface voids in the coarse aggregates, and thus impart additional stability. The gradings of aggregates for two thicknesses of penetration macadam layer are given in Table 4.2, which also gives quantities of both aggregates and binder. Various physical requirements of aggregates are given at Table 4.3.

Table 4.2 Grading Requirements for coarse Aggregates and Key Aggregates for Bituminous penetration Macadam

IS Sieve Designation (mm)	Cumulative per cent by Weight of Total Aggregate, Passing			
	For 50 mm compacted thickness		For 75 mm compacted thickness	
	Coarse Aggregate	Key Aggregate	Coarse Aggregate	Key Aggregate
63 mm	- -	- -	100	- -
45 mm	100	- -	58-82	- -
226.5 mm	37-72	- -	- -	100
22.4 mm	- -	100	5-27	50-75
13.2 mm	2-20	50-75	- -	- -
11.2 mm	- -	- -	- -	5-25
5.6 mm	- -	5-25	- -	- -
2.8 mm	0-5	0-5	0-5	0-5
Approx. Loose Aggregate Quantities Cu. (m/m^2)	0.06	0.015	0.09	0.018
Binder Quantity (Penetration Grade)(1) (Kg/m^2)	5		6.8	

Note : (1) If cutback is used. adjust binder quantity such that the residual bitumen is equal to the values in this Table.

Table 4.3. Requirements for Coarse Aggregates and Key Aggregates for Bituminous Penetration Macadam

Property	Test	Specification
Cleanliness	Grain size analysis[1]	Max 5 per cent passing 0.075 mm sieve
Particle shape	Flakiness and Elongation Index (Combined)[2]	Max 30 per cent
Strength *	Los Angeles Abrasion Value[3]	Max 40 per cent
	Aggregate Impact Value[3]	Max 30 per cent
Durability	Soundness:[4]	
	Sodium Sulphate	Max 12 per cent
	Magnesium Sulphate	Max 18 per cent
Water Absorption Stripping	Water absorption[5]	Max 2 per cent
	Coating and Stripping of Bitumen Aggregate Mixtures[6]	Minimum retained coating 95 per cent
Water Sensitivity	Retained Tensile Strength[7]	Min 80 per cent

Notes:
1. IS: 2386 (Part-1)
2. IS: 2386 (Part-1) (the elongation test to be done only on non-flaky aggregates in the sample)
3. IS: 2386 (Part-4*)
4. IS: 2386 (Part-5)
5. IS: 2386 (Part-3)
6. (IS:6241)
7. The water sensitivity test is to be carried out if the minimum retained coating in the stripping test is less than 95%

* Aggregate may satisfy requirements of either of these two tests.

(ii) The binder should be paving bitumen of suitable penetration grade within the range of S-35 to S-90 as per IS:73 or approved cutback or emulsion as per IS: 217 or 454 or 8887. Further guidance on selection of binder is given in para 2.4, whereas, in a coated macadam, a binder content of a minimum of 3 per cent is generally used, the quantity of binder (including that for seal coat) needed for construction of a penetration macadam is of the order of 6 per cent. Thus, some extra binder is needed for construction of a penetration macadam, and this is often considered to offset any advantage it has in terms of avoidance of us of hot-max plant and paver.

4.2.5. Built-up spray grout (Clause 506 of Ministry's Specifications)

4.2.5.1. Description: It consists of a two- layer composite construction of compacted crushed coarse aggregates with application of bituminous binder after each layer and key aggregates on top for the second layer. It is similar to Penetration Macadam but with less interlock and binder. The thickness of a single course is 75 mm

4.2.5.2. Use: It is used only for emergency repair work and other temporary constructions.

4.2.5.3. Materials

(i) **Aggregates:** The aggregates should satisfy the various physical requirements laid down in Table 4.3. The grading requirements of coarse and key aggregates are given at Table 4.4. The quantity of coarse aggregates in the first and second layers is 0.5 cum per 10 sq.m while the key aggregate on second application of binder should be 0.13 cum,. per 10 sq m.

Table 4.4 Grading Requirements for Coarse Aggregates and key Aggregates for Built-up Spray Grout

IS Sieve Designation (mm)	Cumulative Per cent By Weight of Total Aggreates Passing	
	Coarse Aggregate	Key Aggregate
53.0	100	- -
26.5	40-75	- -
22.4	- -	100
13.2	0-20	40-75
5.6	- -	0-20
2.8	0-5	0-5

(ii) **Binder:** the bitumen should be paving bitumen of penetration grade as per IS: 73 and of penetration grade 30/40, 60/70 or 80/100. The actual grade of bitumen should be appropriate to the region, traffic, rainfall and other environmental conditions. Guidelines on selection of the grade of bitumen are given in Para 2.4. The quantity of binder to be used should be 15 kg/ 10 sq. m (in terms of residual bitumen) for each of the first and second sprays.

4.2.6. Surface dressing (Clause 510 of Ministry's Specifications)

4.2.6.1. Description: Surface dressing, also Known by the term surface treatment in the USA., is a form of construction, whereby, a thin film of bituminous binder is sprayed onto the road surface, covered with a layer of stone chippings and well rolled. The bituminous film acts as a water- proofing seal. The stone chippings protect the film of binder from damage by vehicles and form a durable, skid-resistant and dust-free wearing surface.

The binder and chippings can be applied in one application each, when the work is called single coat surface dressing, or in multiple applications, when the work is called two or more coats of surface dressing. If two coats of surface dressing are to be done, it is customary in India to have a course consisting of larger stone chippings, and therefore heavier application of bitumen binder, followed by a lighter course of smaller chipping and less binder. The smaller chippings of the second application will normally fit into the interstices between the larger chippings of the first application, thus. locking them in place and giving the combined layer much greater stability.

The chippings can be applied with precoating by binder or without. Precoating can serve to promote adhesion, particularly in cases when the aggregate being used does not have a high natural affinity for bitumen. several precoating agents may be used, including emulsions and cutbacks.

4.2.6.2. Purpose: Surface dressing is used in a variety of situations to perform various functions. These are:-

1. As a surfacing in its own right, in the case of relatively lightly trafficked roads, over gravel or other untreated road bases, often to prevent gravel loss, and particularly to reduce dust nuisance.
2. To protect freshly laid water-bound-macadam or similar unbound bases from the action of pneumatic tyred vehicles which, unless prevented from doing so, tend to draw out much of the fines from the macadam and thus deprive it of stability.
3. To act as a water-proof seal and prevent the entry of water into the lower layers of a road pavement. For longer term water proofing,
4. To arrest the deterioration of an existing bituminous surface which is showing signs of distress, as part of periodic maintenance of roads. It is then known also as a seal coat.
5. To increase the skid resistance of smooth surface.
6. To act as a temporary bituminous surfacing on newly constructed roads so as to allow for settlements due to traffic before costlier bituminous layers are provided.

It should be noted that surface dressing is a thin treatment and does not enhance the structural strength of the pavement. Similarly, if the existing road is full of irregularities and undulations, it does nothing to improve riding quality.

4.2.6.3. Materials

1. **Binder:**

The binder to be used in surface dressing should have a viscosity. at the time of application. such that it is fluid enough to permit uniform spraying. After the cover the cover aggregates are rolled into position, the binder should become hard enough to hold them in position against displacement by traffic.

For guidance on selection of the bituminous binder, reference may be made to para 2.4.2.

2. **Stone Chippings:**

The choice of chippings size is generally governed by the extent of embedment expected of the chippings into the road surface which, in turn, is governed by the softness of the existing surface onto which the surface dressing is to be constructed, and the volume of heavy traffic expected to pass over it. larger chipping sizes are required for use with softer bases and heavier traffic. sizes and grading requirements are given at Tables 4.5 and 4.6 Guidance on the selection of chipping size is at ***Appendix-2.*** The physical requirements are at Table 4.3

Table 4.5 Recommended Nominal Sizes of Stone Chippings (Millmetres)

Type of surface	Approximate number of commercial vehicles with an Unladen weight Greater Than 1.5 Tonnes currently Carried per Day in the Lane Under Consideration				
	2000-4000	1000-2000	200-1000	20-200	Less than 20
Very hard	10	10	6	6	6
Hard	13	13	10	6	6
Normal	19+	13	10	10	6
Soft	*	19+	13	13	10
Very Soft	*	*	19	13	10

Note: The size of stone chippings is related to the mid-Point of each lane traffic category. Light traffic conditions may make the next smaller size of stone more appropriate.

+ Very particular care should be taken when using 19mm chippings to ensure that no loose materials remain on the surface when the road is opened to unrestricted traffic as there is a high risk of windscreen breakage.

*Unsuitable for surface dressing.

Table 4.6 Grading Requirements for Chips Surface Dressing

IS Sieve Designation (mm)	Cumulative per cent by weight of total aggregate passing for the following nominal sizes (mm)			
	19	13	10	6
26.5	100	-	-	-
19.0	85-100	100	-	-
13.2	0-40	85-100	100	-
9.5	0-7	0-40	85-100	100
6.3	-	0-7	0-35	85-100
4.75	-	-	0-10	-
3.35	-	-	-	0-35
2.36	0-2	0-2	0-2	0-10
0.60	-	-	-	0-2
0.075	0-1.5	0-1.5	0-1.5	0-1.5
Minimum 65 per cent by weight of aggregate	Passing 19 mm, retained 13.2 mm	Passing 13.2 mm, retained 9.5 mm	Passing 9.5 mm, retained 6.3 mm	Passing 6.3 mm, retained 3.35 mm

4.2.6.4. Quantities: The quantity of bituminous binder required will depend on the nominal size and the shape of the surfacing aggregate to be used, and on the expected extent of its embedment into the surface. Detailed guidance on the design of surface dressing spread rates is given at ***Appendix-3.*** Table 4.7 is a guide to the approximate rates that may be excepted under average conditions.

Table 4.7. Rates of Spread of Binder and Chippings

Nominal Size of chippings (mm)	Binder (Pen. Grade) kg/10 m^2	Chippingsm^3/m^2
19	12.0	0.015
13	10.0	0.010
10	9.0	0.008
6	7.5	0.004

When cutbacks and emulsions are used. the quantity of binder must be increased so that the residual quantity of binder, after dispersment of the cutting agent or the water portion of the emulsion, is as giver in Table 4.7.

- The recommended nominal size of stone chippings are given in Table 4.5.
- The grading requirements for chippings are given in Table 4.6
- The quantity of chippings for various nominal sizes are given in Table 4.7.

4.2.6.5 Anti-stripping agent: Where a significant loss of stone chippings during trafficking in wet weather is considered to be a risk, an adhesion agent may be added to the binder in accordance with ***Appendix-1.*** In order to test the effectiveness of the anti- stripping agent, the test given in ***Appendix-1*** should be used.

4.2.7. Fog spray (Clause 518 of Ministry's Specifications)

4.2.7.1. Description: A fog spray (or fog seal) is a light application of a slow-setting emulsion, diluted with water, to an existing surface.

4.2.7.2. Use/ Purpose

1. To renew an old bituminous surface that has become dry and brittle with age.
2. To seal small cracks and surface voids.
3. To inhibit ravelling and whip-off of chippings by traffic on newly finished surface dressing.

It is mainly a maintenance treatment in its own right, and may not be regarded as a substitute for surface dressing, renewal seal coat or slurry seal. By penetrating into the cracks and voids and coating the loose aggregates on the surface , it can prolong the life of pavements and may delay the time when major maintenance or rehabilitation is needed.

4.2.7.3. Materials : Grades of bituminous emulsion normally used are SS-1, SS-l h, CSS-1 or CSS-l h. The grades SS-l h and CSS-l h are, however, to be preferred. (The SS grade of emulsion specified in IS:8887-1995 has the same range of viscosity as the above grades and may also be considered.

4.2.7.4. Quantities: the quantity of emulsion used is usually in the range of 5 to 10 liters per 10 sqm of diluted materials, prepared by adding emulsion and water in equal proportions.

The precise amounts to be used. will depend on the degree of cracking or ravelling. dryness and texture of the surface over which the fog spray is to be applied. if the applied emulsion is found to be in excess, a light sand dusting may have to be used as in the case of prime coat.

4.3 Pre-mixed Aggregate and Bitumen mixtures

The common types of construction falling under this category are:-

1. Bituminous Macadam
2. Dense- graded Bituminous Material
    (i) Dense Bituminous Macadam
    (ii) Semi-Dense Bituminous concrete
    (iii) Bituminous concrete
3. Open-Graded premix surfacing
4. Close-Graded Premix surfacing
5. Premix seal Coat
6. Mastic Asphalt
7. slurry seal
8. Recycling of Bituminous pavement
9. Stone Mastic Asphalt
10. Bituminous Cold Mix (including Gravel Emulsion)
11. Sand Asphalt Base Course
12. High performance Base
13. Emerging Materials

The Pre- mix Methods /Plant mixes have a number of advantages over the penetration or layered systems. In these methods, a proper. uniform coating of coarse and fine aggregates by the bituminous binder is ensured before laying the mix at the site of work, The dense- graded bituminous mixtures are scientifically designed with the optimum binder content determined by established design methods (like, the Marshall Method for hot-mix hot-laid dense- graded mixtures) ensuring a minimum stability, per cent voids in mineral aggregate, per cent air voids, per cent voids filled with bitumen, etc. the speed of construction adopting the Pre-mix Methods/Plant mixes is much higher and also much more effective quality control can be exercised during construction in construction in comparison to the construction of penetration or sprayed layered systems.

For each of the above-mentioned bituminous constructions. a brief description of the type of construction, its use/purpose and detailed information on the materials (both aggregates and bituminous binder) involved are given in paras 4.3.1. to 4.3.15. The detailed information on equipment and construction procedure are, however, given in Chapters 6 and 8 respectively.

4.31. Bituminous macadam Clause 504 of Ministry's Specification)

4.3.1.1. Terminology : Bituminous macadam is also known by other names, such as, Coated macadam and Precoated Macadam. In India, Two types of Bituminous macadam are commonly used:

1. Open-graded Bituminous Macadam, Known in short as Bituminous Macadam (BM)
2. Dense-graded Bituminous Macadam, known in short as Dense Bituminous Macadam (DBM)

This section deals with Open-graded Bituminous Macadam (BM), and the next section deals with Dense Bituminous Macadam.

4.3.1.2. Description: Bituminous Macadam consists of a graded aggregate coated with a bituminous binder. The main source of strength of the mixture is from the mechanical interlooking of the aggregate particles, and the cohesion imparted by the binder. The binder bonds the aggregates together and, during construction, lubricates the aggregate particles, thus facilitating the compaction of the mixture. Because of the open-graded aggregate matrix, the voids content con be as high as 20-25 per cent.

The layer is generally laid to thicknesses of 50 mm to 100 mm.

4.3.1.3. Use/purpose: A layer of Bituminous Macadam serves as a base/binder course, laid immediately after mixing on a previously prepared base.

4.3.1.4. Materials

(A) Aggregates: The aggregate should meet the various physical requirements as laid down on Table 4.3. The Two gradings given in Table 4.8 are commonly used.

Table 4.8 Aggregate Grading for Bituminous Macadam (BM)

Mix Designation	BM Grading 1	BM Garding 2
Normal Aggregate Size	40 mm	19 mm
Layer Thickness	75-100 mm	50-75 mm
IS Sieve (mm)	Cumulative per cent by weight of total aggregate passing	
45	100	- -
37.5	90-100	- -
26.5	75-100	100
19	- -	90-100
13.2	35-61	56-88
4.75	13-22	16-36
2.36	4-19	4-19
0.3	2-10	2-10
0.075	0-8	0-8
Bitumen Content, per cent By Weight of Total Mixture[1]	3.1 to 3.4	3.3 to 3.5
Bitumen Grade	35 to 90	35 to 90

Note 1: These bitumen contents have been found suitable for tropical Indian climates. Appropriate bitumen contents for conditions. in cooler areas of India may be upto 0.5 per cent higher.

Binder : The bitumen content varies from 3 to 4 per cent. The grade of bitumen is 30/40, 60/70 or 80/100. The choice of the grade of bitumen is governed by factors such as:

1. Intensity of Traffic - heavy traffic or difficult site conditions requires binders of high viscosity.
2. Season of the Year - A general reduction in viscosity may be permitted during winter months. Similarly, high viscosity binders are used in summer months. Further guidance on selection of an appropriate grade of bitumen is given in Para 2.4.

4.3.1.5. Recipe mix : The bituminous macadam is basically a recipe type of specification and there is no need for a mix design. For controlling the density of compaction, it is usual to perform the Refusal Density test. Rolling is continued till the density achieved is a minimum of 91 per cent of Percentage Refusal Density (PRD). Guidance on Refusal Density Design is at ***Appendix-5***.

4.3.2. Dense graded bituminous material : Dense Bituminous Macadam (DBM) (Clause 507 of Ministry's Specifications)

4.3.2.1. Description : A description of bituminous macadam has been given earlier in para 4.3.1.2. The same description holds, good for dense bituminous macadam, the only difference being that the stone aggregates are more closely graded. As a result, the resultant mixture is more dense. It may be laid to thicknesses varying from 50 to 200 mm. When the thickness is greater than 100 mm, laying should be carried out in not less than two layers.

4.3.2.2. Use/Purpose : Dense bituminous macadam is used as a base/binder course for pavements subjected to heavy traffic.

4.3.2.3. Materials

A. Coarse Aggregates: The coarse aggregates should consist of crushed rock, crushed gravel or other stones retained on the 2.36 mm sieve. These should be clean, hard, durable, of fairly cubical shape, free from soft pieces, organic or other deleterious substances. The various physical requirements to be satisfied are given in Table 4.9. If the aggregates are of the stripping type, as indicated by IS:6241, the Water Sensitivity test should be performed. In case the aggregates do not pass the Water Sensitivity Test, the bitumen should be treated with an anti-stripping agent. Guidance on the use of anti-stripping agents is given in ***Appendix-I***. If crushed gravel is used, not less than 90 per cent by weight of gravel pieces retained on 4.75 mm sieve should have at least two fractured faces.

B. Fine Aggregates: Fine aggregates should be the fraction passing the 2.36 mm sieve and retained qn the 0.075 mm sieve, consisting of crushed stone or crushed gravel, sand or a mixture of both. These should be clean, hard, durable, dry and free from soft pieces and organic or other deleterious matter. The fine aggregates should have a sand equivalent value (IS:2720, Part-37) of not less than 50. The plasticity index (IS:2720 Part-5) should not exceed 4.

C. Filler: As per the revised Ministry's Specifications, the filler should consist of finely divided mineral matter, such as, rock dust, hydrated lime or cement. The grading limits are as under :

IS Sieve (mm)	Cumulative Per cent Passing by Weight of Total Aggregate
0.6	100
0.3	95-100
0.075	85-100

It should have a plasticity index not greater than 4. This requirement does not apply if filler is lime or cement. When the coarse aggregate is non-calcareous material, 2 per cent by mass of total aggregate of Portland Cement or hydrated lime should be added and the percentage of fine aggregate reduced accordingly. Cement or hydrated lime is not required when the coarse aggregate is limestone. The incorporation of 2 per cent of hydrated lime as above is recommended in all cases for mixtures, which fail to meet the water sensitivity requirement given in Table 4.9.

Table 4.9. Physical Requirements for Coarse Aggregates for Dense Bituminous Macadam

Property	Test	Specification
Cleanliness (dust)	Grain size analysis[1]	Max 5 per cent passing 0.075 mm sieve
Particle shape	Flakiness and Elongation Index (Combined)[2]	Max 30 per cent
Strength*	Los Angeles Abrasion Value[3]	Max 35 per cent
	Aggregate Impact Value[4]	Max 27 per cent
Durability	Soundness:[5]	
	Sodium Sulphate	Max 12 per cent
	Magnesium Sulphate	Max 18 per cent
Water Absorption	Water absorption[6]	Max 2 per cent
Stripping	Coating and Stripping of Bitumen Aggregate Mixtures[7]	Minimum retained coating 95 per cent
Water Sensitivity	Retained Tensile Strength[8]	Min 80 per cent

Notes:
1. IS: 2386 (Part-1)
2. IS: 2386 (Part-1)
   (the elongation test to be done only on non-flaky aggregates in the sample)
3. IS: 2386 (Part-4*)
4. IS: 2386 (Part-4*)
5. IS: 2386 (Part-5)
6. IS: 2386 (Part-3)
7. (IS:6241)
8. AASHTO T283**

* Aggregate may satisfy requirements of either of these two tests.

** The water sensitivity test is only required if the minimum retained coating in the stripping test is less then 95 per cent

The combined grading of coarse aggregates, fine aggregates and filler should fall within the grading limits given in Table 4.10. The type of binder and minimum amount of binder are also indicated in Table 4.10. Guidance on the selection of grade of bitumen is given in para 2.4.

Table 4.10. Composition of Dense Graded Bituminous Macadam Pavement Layers

Grading	1	2
Nominal aggregate size	40 mm	25 mm
Layer Thickness	80-100 mm	50-75 mm
IS Sieve[1] (mm)	Cumulative % by weight of total aggregate passing	
45	100	
37.5	95-100	100
26.5	63-93	90-100
19	-	71-95
13.2	55-75	56-80
9.5	-	-
4.75	38-54	38-54
2.36	28-42	28-42
1.18	-	-
0.6	-	-
0.3	7-21	7-21
0.15	-	-
0.075	2-8	2-8
Bitumen content per cent by mass of total mix[2]	Min 4.0	Min 4.5
Bitumen grade (pen)	65 to 90	65 to 90

Notes: [1] The combined aggregate grading shall not vary from the low limit on one sieve to the high limit on the adjacent sieve.

[2] Determined by the Marshall method.

4.3.2.4. Binder content : The binder content should be optimised to achieve the requirements of the mixture set out in Table 4.11. The Marshall method for determining the optimum binder content should be adopted as described in the Asphalt Institute Manual MS-2, replacing the aggregates retained on the 26.5 mm sieve by the aggregates passing the 26.5 mm sieve and retained on the 22.4 mm sieve, where appropriate, approved by the Engineer.

Alternatively, for the Dense. Bituminous Macadam mixture, the modified Marshall method described in MS-2 may be used. This method requires modified equipment and procedures, particularly the minimum stability values in the Table 4.11 should be multiplied by 2.25 and the minimum flow should be 3 mm.

Table 4.11. Requirements for Dense Bituminous Macadam

Minimum stability (kN at 60°C)	9.0
Minimum flow (mm)	2
Minimum flow (mm)	4
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Per cent air voids	3-6
Per cent voids in mineral aggregate (VMA)	See Table 4.12 below.
Per cent voids filled with bitumen (VFB)	65-75

The requirements for minimum per cent voids in mineral aggregate (VMA) are set out in Table 4,12.

Table 4.12. Minimum Voids in Mineral Aggregates for Dense Bituminous Macadam

Nominal Maximum Particle Size[1] (mm)	Minimum VMA, Per Cent Related to Design Air Voids, Per cent[2]		
	3.0	4.0	5.0
9.5	14.0	15.0	16.0
12.5	13.0	14.0	15.0
19.0	12.0	13.0	14.0
25.0	11.0	12.0	13.0
37.5	10.0	11.0	12.0

Note [1]The nominal maximum particle size is one size larger than the first sieve to retain more than 10 per cent.
[2]Interpolate minimum voids in the mineral aggregate (VMA) for design air void values between those listed.

4.3.3. Dense graded bituminous material : Semi-Dense Bituminous Concrete (SDBC) (Clause 508 of Ministrys Specifications)

4.3.3.1. Description : The semi-dense bituminous concrete is a variant of bituminous concrete, the difference being a lower binder content and the aggregate used being less dense-graded. It is laid in a single course over a previously prepared bituminous base.

4.3.3.2. Use/Purpose : It is used as a binder/wearing course on roads carrying relatively lower traffic in terms of equivalent standard axle loads (esa), generally less than 10 msa.

4.3.3.3. Materials : For coarse aggregates, fine aggregates and filler, various physical requirements as given in paras 4.3.2.3 (A), 4.3.2.3 (B) and 4.3.2.3 (C) will apply, except the Polished Stone Value should be greater than 55 per cent. The combined grading of coarse aggregates, fine aggregates and filler should fall within the limits given in Table 4.13.

The binder should be a penetration grade bitumen as given in Table 4.13. The binder content should be optimised, following the Marshall method of mix design, to achieve the requirements of the mixture, set out in Table 4.14.

Table 4.13. Composition of Semi-Dense Bituminous Concrete (SDBC)

Grading	1	2
Nominal aggregate size	13 mm	10 mm
Layer Thickness	35-40 mm	25-30 mm
IS Sieve’ (mm)	Cumulative % by weight of total aggregate passing	
45		
37.5		
26.5		
19	100	
13.2	90-100	100
9.5	70-90	90-100
4.75	35-51	35-51
2.36	24-39	24-39
1.18	15-30	15-30
0.6	-	-
0.3	9-19	9-19
0.15	-	-
0.075	3-8	3-8
Bitumen content per cent by mass of total mix[2]	Min 4.5	Min 5.0
Bitumen grade (pen)	65*	65*

Notes: [1]The combined aggregate grading shall not vary from the low limit on one sieve to the high limit on the adjacent sieve.

[2]Determined by the Marshall method.

*Only in exceptional circumstances, 80/100 penetration grade may be used.

4.3.3.4. Mix design : The semi-dense bituminous concrete mix is designed on the basis of Marshall procedure. The requirements are set forth in Table 4.14.

Table 4.14. Requirements for Semi-Dense Bituminous Concrete

Minimum stability (kN at 60°C)	8.2
Minimum flow (mm)	2
Minimum flow (mm)	4
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Per cent air voids	3-5
Per cent voids in mineral aggregate (VMA)	See Table 4-12
Per cent voids filled with bitumen (VFB)	65-78

The requirements of minimum per cent Voids in the Mineral Aggregate (VMA) should be the same as set out in Table 4.12.

4.3.4. Dense graded bituminous material : Bituminous Concrete (BC) (Clause 509 of Ministry's Specifications)

4.3.4.1. Description : Bituminous concrete layer is composed of a thoroughly compacted dense-graded bituminous mixture of very well graded coarse and fine aggregates with filler and relatively higher amount of bitumen compared to DBM and SDBC.

4.3.4.2. **Use/Purpose :** A Bituminous Concrete layer serves as a wearing course for heavily trafficked highways.

4.3.4.3. Materials

A. **Aggregates:** For coarse aggregates, fine aggregates and filler, various physical requirements as given in paras 4.3.2.3. (A), 4.3.2.3 (B) and 4.3.2.3 (C) and Table 4.9 will apply except that (i) Los Angeles Abrasion Value must not exceed 30 per cent, (ii) Aggregate Impact Value must not exceed 24 per cent and (iii) the Polished Stone Value must be more than 55. The combined grading of coarse aggregates, fine aggregates and filler should fall within the limits given in Table 4.15.

B. **Binder:** The binder should be a 60/70 penetration grade bitumen. The binder content should be optimised following the Marshall Method of mix design, to achieve the requirements of the mixture set out in Table 4.16.

Table 4.15. Composition of Bituminous Concrete

Grading	**1**	**2**
Nominal aggregate size	**19 mm**	**13 mm**
Layer Thickness	**50-65 mm**	**30-45 mm**
IS Sieve’ (mm)	**Cumulative % by weight of total aggregate passing**	
45		
37.5		
26.5	100	
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content per cent by mass of total mix[2]	5.0-6.0	5.0-7.0
Bitumen grade (pen)	65	65

Notes: The combined aggregate grading shall not vary from the low limit on one sieve to the high limit on the adjacent sieve.
‘Determined by the Marshall method.

4.3.4.4. **Mix Design :** Mix design is usually done by the Marshall method. The requirements for the mix are given in Table 4.16.

Table 4.16. Requirements for Bituminous Concrete

Minimum stability (kN at 60°C)	9.0
Minimum flow (mm)	2
Minimum flow (mm)	4
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Per cent air voids	3-6
Per cent voids in mineral aggregate (VMA)	See Table 4.12
Per cent voids filled with bitumen (VFB)	65-75
Loss of stability on immersion in water at 60°C (ASTM D1075)	Minimum 75 per cent retained strength

4.3.5. Open-graded premix surfacing (Clause 511 of Ministry's Specifications)

4.3.5.1. Description : Open-graded Premix Surfacing, also known by other names, such as, Precoated Chipping Carpet and Open-Graded Chipping Carpet, is a popular specification in India for a thin carpet. It is generally laid to a thickness of 20 mm. A seal coat is provided to render it less permeable to water.

4.3.5.2. Use/Purpose : It serves as a wearing course on lightly trafficked roads or for temporary improvement and maintenance.

4.3.5.3. Materials

A. **Aggregates:** The aggregates should conform to the quality requirements given in para 4.3.2.3 (A) and Table 4.9 except that (i) flakiness and elongation indices (total) must not exceed 30 per cent, (ii) The Polished Stone Value should not be less than 55, and (iii) the water absorption should be limited to 1 per cent. There is no continuous grading specified for the aggregates. The two types of aggregates are mixed together : 13.2 mm size (passing 22.4 mm and retained on. 11.2 mm) and 11.2 mm (passing 13.2 mm and retained on 5.6 mm) in a 2:1 proportion.

The quantity of 13.2 mm size is 0.18 cum per 10 sqm and that for the 11.2 mm is 0.09 cum per 10 sqm.

B. **Binder:** The binder can be a penetration grade bitumen or a suitable grade of cutback or emulsion. Guidance on the selection of a suitable type and grade of a binder is given in para 2.4.

The quantity of binder for obtaining the premixed material is as tinder:

Penetration Grade. Bitumen : 14.6 kg per 10 sqm

Emulsion or cutback : 20-23 kg per 10 sqm

A seal coat is normally provided on an open-textured premix carpet to make the finished surface less pervious to water.

4.3.6. Close-graded premix surfacing/Mix Seal Surfacing (MSS) (Clause 512 of Ministry's Specifications)

4.3.6.1. Description : Close-graded premix surfacing or Mix Seal Surfacing (MSS) is a fairly open graded mix used as a thin carpet. Thicknesses in the range of 12 mm to 40 mm can be laid. In India it is customary to provide 20 mm thickness. The material is an alternative to the open graded premix carpet with seal coat and has the advantage that it may be constructed in one operation.

4.3.6.2. Use/ Purpose : It serves as a thin wearing course for lightly trafficked roads.

4.3.6.3. Materials

(A) **Aggregates:** The aggregates should conform to the quality requirements given in para 4.3.2.3 (A) and Table 4.9 except that (i) Flakiness and Elongation indices (total) must not exceed 30, (ii) the Polished Stone Value should not be less than 55 and (iii) the water absorption should be limited to 1 per cent.

Two types of close-graded premix surfacing are used, Type A and Type B, the aggregate gradings for which are given in Table 4.17.

Type A material is used for thicknesses of 20 to 25 mm.

For a 20 mm thick mix seal, the quantity of aggregates needed is approximately 0.27 cum per 10 sqm area.

Table 4.17. Aggregate Gradation

IS Sieve Designation	Cumulative per cent by weight of total aggregate passing	
	Type A	Type B*
13.2 mm	--	100
11.2 mm	100	88-100
5.6 mm	52-88	31-52
2.8 mm	14-38	5-25
90 Micron	0-5	0-5

* Not applicable for 20 to 25 mm thickness

(B) **Binder:** The binder used is generally a bitumen of penetration grade 60/70 or 80/100. The quantity of binder used is approximately 5 per cent by weight of the mix. Thus, for a 20 mm thick layer, approximately 22 kg of binder is needed for an area of 10.0 sqm for Type A and 19 kg per 10 sqm for Type B.

4.3.7. Premix seal coat (Clause 513 of Ministry's Specifications)

4.3.7.1. Description : Premix seal coat is a thin application of a bituminous course over another bituminous surface.

4.3.7.2. Use : It is intended for sealing the voids in the bituminous surface over which it is laid and is needed only for those surfaces, which are open-textured, e.g., an open-graded premix carpet.

4.3.7.3. Materials :

(A) **Aggregates:** The quality requirements for aggregates are the same as given in para 4.3.6.3(A).

The premix seal coat involves mixing of aggregates, such as, sand or grit (passing 2:36 mm sieve and retained on 180 micron size) of a quantity of 0.06 cum per 10 sqm with binder.

(B) **Binder:** The requirements for the type and grade of binder are the same as for Open-Graded Premix Surfacing.

The quantity of penetration grade bitumen used is 6.8 kg per 10 sqm. If an emulsion or cutback is used, the quantity is 10 to 12 kg per 10 sqm.

4.3.8. Mastic asphalt (Clause 515 of Ministry's Specifications)

4.3.8.1. Description : Bitumen mastic, alternatively known as Mastic Asphalt, is a mixture of bitumen, mineral filler and fine aggregates in suitable proportions designed to yield a voidless compact mass. Its consistency is such that it flows like a viscous fluid at temperatures of around 200°C but, on cooling to normal temperatures, it solidifies into a dense mass. Thus, its construction requires no compacting effort.

The material derives its mechanical strength from the resistance to strain of the continuous matrix of fine aggregates, filler and bitumen. The final product is very hard, durable, fully impermeable, resistant to deformation and self-healing. It is normally laid to thicknesses of 20-50 mm.

4.3.8.2. Use/Purpose : Because of its superior properties, it is used as a wearing course material for heavy duty pavements, city streets carrying high volume of traffic, bus stops where heavy tangential forces are expected, junctions where cornering stresses are predominant and on bridge decks. Thin mastics are also used for footways. It does not, however, provide good skid resistance and measures are normally taken to enhance this aspect of its performance.

4.3.8.3. Materials

(A) Coarse Aggregates: The coarse aggregates should consist of crushed stone, crushed gravel/shingle or other stones. They should be clean, hard, durable, of fairly cubical shape, uncoated and free from soft or flaky pieces, organic or other deleterious substances. They should satisfy the physical requirements given in Table 4.9 and para 4.3.5.3(A).

The percentage and grading of the coarse aggregate to be incorporated in the mastic asphalt depending upon the thickness of the finished course should be as specified in Table 4.18.

Table 4.18. Grade and Thickness of Mastic Asphalt Paving and Grading of Coarse Aggregate

Application	Thickness range mm	Nominal size of coarse aggregate (mm)	Coarse aggregate content, per cent by mass of total mix
Roads and carriageways	25-50	13	40 ± 10
Heavity stressed areas, i.e. junctions and toll plazas	40-50	13	45 ± 10

Norminal size of coarse aggregate IS Sieve (mm)	13 mm Cumulative % passing by weight
19	100
13.2	88-96
2.36	0-5

(B) **Fine Aggregates:** The fine aggregate should be the fraction passing the 2.36 mm and retained on the 0.075 mm sieve consisting of crusher run screening, natural sand or a mixture of both. These should be clean, hard, durable, uncoated, dry and free from soft or flaky pieces and organic or other deleterious substances.

(C) **Filler:** The filler should be limestone powder passing the 0.075 mm sieve and shall have a calcium carbonate content of not less than 80 per cent by weight when determined in accordance with IS:1195-1978.

The grading of the fine aggregate inclusive of filler should be as given in Table 4.19.

Table 4.19. Grading of Fine Aggregate for Mastic Asphalt (Inclusive of Filler)

I.S. Sieve	Percentage by weight of aggregate
Passing 2.36 mm but retained on 0.600 mm	0 -25
Passing 0.600 mm but retained on 0.212 mm	10-30
Passing 0.212 mm but retained on 00.75 mm	10-30
Passing 0.075	30-55

(D) **Binder:** The binder should be a paving grade bitumen meeting the requirements given in Table 4.20.

Table 4.20. Requirements for Physical Properties of Binder

Property		Test method	Requirement
penetration at 25°C		IS:1203	15 ± 5*
Softening point, °C		IS:1205	65 ± 10
Loss on hearting for 5h at 163°C, per cent by mass	Max.	IS: 1212	2.0
Solubility in trichloroethylene, per cent by mass	Min.	IS: 1216	95
Ash (mineral matter), per cent by mass	Max.	IS: 1217	1.0

* In cold climatic regions (temperature ≤ 10 °C), a softer penetration grade of 30/40 may be used.

4.3.8.4. Mix design : The mastic asphalt should have a hardness number, (defined as the depth, in hundredths of a cm, to which a standard steel rod will penetrate at standardised temperature and loading conditions) at the time of manufacture and prior to the addition of coarse aggregate, of 60 to 80 at 25°C and 10 to 20 at 25°C at the time of laying after the addition of coarse aggregate.

The hardness number should be determined in accordance with the method specified in IS: 1195-1978.

The binder content should be so fixed as to achieve the requirements of the mixture as above and should be in the range of 14 to 17 per cent by weight of total mixture.

4,3.9. Slurry seal (Clause 516 of Ministry's Specifications)

4.3.9.1. Description : Slurry Seals are a mixture of well-graded fine aggregate, portland cement filler, bituminous emulsion and additional water. When freshly mixed, they have a thick consistency and can be spread to a thickness of 1.5 - 5 mm.

4.3.9.2. Use/Purpose : Slurry seals can be used for both preventive and corrective maintenance of aged bituminous surfaces and surfaces with fine cracks. They seal surface cracks, fill voids and minor depressions, and provide a more even riding surface or base for further treatment. They may also be used on top of a single coat surface dressing.

4.3.9.3. Materials

(A) Aggregate: The aggregate can be crushed rock or slag and may be blended, if required, with clean, sharp, naturally occurring sand free from soft or flaky pieces and organic and other deleterious substances to produce a grading as given in Table 4.21. The aggregates should meet the requirements of the film stripping test (IS:6241) and a suitable amount and type of anti-stripping agent added, as may be needed.

(B) Filler: It is normal to use ordinary Portland Cement, hydrated lime or other additives to control consistency, segregation and setting rate. The proportion of the additive should not normally exceed 2 per cent by weight of dry aggregates.

(C) Binder: A bituminous emulsion of suitable grade as per the guidelines given inpara 2.4.3 should be used. Generally, emulsion for slurry seal should be capable of producing a slurry seal that will develop early resistance to traffic and rain, and is sufficiently stable to permit mixing with the specified aggregate, without breaking during the mixing and laying processes. If early traffic is to be permitted, the emulsion should be of the rapid setting type. When setting time is not critical, a slow setting emulsion can be used.

(D) Water: Water should be of such quality that the bitumen will not be separated from the emulsion before the slurry seal is in place. The water should be tested during trial construction.

(E) Mixture Design: A range of residual binder contents for each aggregate grading is given in Table 4.21. The optimum mixture design for the aggregate, additive, filler, water and bituminous emulsion mixture should ber determined in accordance ‘with ASTM D3910.

4.10. Recycling of bituminous pavement (Clause 517 of Ministry's Specifications)

4.3.10.1. Description : Recycling process can be categorised into in-situ recycling (where processing takes place in-situ) and central plant recycling (where the reclaimed material is processed off site). The process can be achieved by the hot-mix or cold-mix techniques. The work involves the following steps :

1. Removal of the existing surface
2. Testing and evaluation of the removed materials
3. Determining the optimum blend of reclaimed materials, additional material and binder
4. Mixing
5. Laying and compacting

Table 4.21. Aggregate Grading, Binder Content and Approximate Coverage Rate for Slurry Seal

Sieve Size (mm)	Percentage by mass passing		
	Finished thickness of sealing		
	5 mm	3 mm	1.5 mm
9.5	100	- -	- -
4.75	90-100	100	- -
3.35	- -	80-100	100
2.36	65-90	75-100	95-100
1.18	45-70	55-90	70-95
0.600	30-50	35-70	55-75
0.300	18-30	20-45	30-50
0.150	10-21	10-25	10-30
0.075	5-15	5-15	5-15
Quantity of residual binder, percentage by mass of aggregate	7.5-13.5	10-16	12-20
Approxmiate coverage rate (kg/m^2)	8-15	4-6	2-4

4.3.10.2. Use/Purpose : Recycling of a bituminous pavement is the reuse, after some processing, of a pavement material that has served its first intended purpose. The advantages of recycling are :

(i) reduction in excess of height`of pavement that may be caused by overlays
(ii) effective use and, conservation of materials
(iii) economy

4.3.10.3. Removal, of the existing surface : The existing surface can be removed by the hot removal process or the cold removal process. In the hot process, the road surface is heated by suitable means and milled. In the cold process, the removal is done by cold milling or planing machines or by other equipment, such as, scarifiers, rippers, grid rollers, etc.

4.3.10.4. Testing, evaluation and mix design : Samples of the removed material are tested for composition, analysis and properties of the binder. The results of mechanical analysis usually reveal deficiencies in the grading of the material and from it can be estimated the types and quantities of various sizes of aggregates and filler to be added to meet the grading requirements. The properties of the bitumen in the recovered material would reveal its penetration, and thus give an indication of the extent of its oxidation. The quantity of fresh binder and any recycling agents needed to rejuvenate the existing binder may then be determined. The following formula, based on field experience, is used for this purpose:

$$Pen_v = (pen_s/pen_f^{\,b})^{1/a}$$

Where Pen_v = Penetration of new bitumen
Pen_s = penetration of binder of the final mix
Pen_f = penetration of binder in existing mix
a = proportion of new bitumen
b = proportion of old binder
(where $a+b = 1$)

4.3.11. Stone mastic asphalt (New Specification)

4.3.11.1. Description : Stone Mastic Asphalt (SMA) is a gap-graded mixture with about 70-80 per, cent stone content, 6-7 per cent of binder, 8-12 per cent of filler and about 0.3 per cent fibres or similar modifier. The high stone content of the mixture forms a skeleton-type structure offering high resistance to deformation. The fibres or modifier prevent drainage during manufacture, transportation and laying. The mixture is laid at a thickness of 30 to 45 mm.

4.3.11.2. Use/Purpose : The material being very durable and rut resistant,' it is used in very heavily trafficked situations.

4.3.11.3. Materials

(A) **Coarse Aggregate:** The coarse aggregates consist of crushed rock or crushed slag. They should be clean, hard, durable, of fairly cubical shape, free from soft pieces, organic or other deleterious substances. The aggregates should satisfy the physical requirements set forth in Table 4.22. If the aggregates are of the stripping type as indicated by IS:6241, the water sensitivity test should be performed. If the aggregates do not pass the water sensitivity test, the bitumen should be treated with anti-stripping agents of approved quality in suitable doses (Guidelines in Appendix-1).

(B) **Fine Aggregates:** comprising fraction passing 2.36 mm sieve and retained on the 0.075 mm sieve, may be blended with not more than 50 per cent natural sand. These should be clean, hard, durable, dry and free from soft pieces and organic or other deleterious substances. The sand equivalent test (a rapid field test to show the relative amounts of plastic fines in graded aggregates and soils)m(IS:2720 (Part 37) value for the fine aggregate should not be less than 50, and fines should be non-plastic.

(C) **Filler:** The filler should be in accordance with para 4.3.2.3 (C) except that added filler should be hydrated lime, crushed limestone or Portland Cement and should be at least 2 per cent by mass of total aggregate.

The combined grading of coarse aggregates, fine aggregates and filler should conform to Table 4.23.

Table 4.22. Physical Requirements for Coarse Aggregates for Stone Mastic Asphalt (SMA)

Property	Test	Specification
Cleanliness	Grain Size analysis[1]	< 2 per cent passing 0.075 mm sieve
Particle shape	Combined Flakiness and Elongation index[2]	< 30 per cent
Strenght*	Los Angeles Abrasion Value[3]	< 25 per cent
	Aggregate Impact Value[4]	< 18 per cent
Polishing	Polished Stone Value[5]	> 55
Durability	Soundness:[6]	< 12 per cent
	Sodium Sulphate	< 18 per cent
	Magnesium Sulphate	
Water absorption	Water absorption[7]	< 2 per cent
Stripping	Coating and Stripping of Bitumen Aggregate Mixture[8]	Retained Coating ≥ 95 per cent
Water Sensitivity**	Retained Tensile Strenghth[9]	> 80 per cent

Notes:
1. IS: 2386 (Part-1)
2. IS: 2386 (Part-1) (the elongation test to be done only on non-flaky aggregates in the sample)
3. IS: 2386 (Part-4)*
4. IS: 2386 (Part-4)*
5. BS: 812 (Part-114)
6. IS: 2386 (Part-5)
7. IS:2346 (Part-3)
8. IS:6241
9. AASHTO T283**

* Aggregate may satisfy requirements of either of these two tests.

** The water sensitivity test is only required if the minimum retained coating in the stripping test is less then 95 per cent

(D) **Binder:** The binder should be either a modified binder or alternatively, bitumen with stabilising additive. The bitumen should be a paving bitumen of penetration grade as indicated in Table 4.23. If modified binder is used, the base bitumen should have a nominal penetration of S 65, S 90 or S 200; Guidance on use of modified binders is given in para 2.2.4.

The fibres or modifier ensures that the binder does not drain during transport and handling. The stabilising additives are cellulose, mineral matter or other suitable fibre. The quantity of stabilising agent is atleast 0.3 per cent of the weight of the total mix.

(E) **Stabilising Additive or Modified Binder:** When paving bitumen complying with IS:73 is used as the binder, at least 0.3 per cent by mass of total mixture of stabilising additive should be used to ensure binder drainage does not occur during transport and handling. Stabilising additives should be cellulose or mineral or other suitable fibre. Details of the Binder Drainage Test are given at ***Appendix-6.***

(F) **Aggregate Grading and Binder Content :** When tested in accordance with IS:2386 (Part 1) (wet sieving method), the combined grading of the coarse and fine aggregates and added filler for the particular mixture should be within the limits shown in Table 4.23. The type and quantity of bitumen, and appropriate thickness, are also indicated for each mixture type.

Table 4.23. Composition of Stone Mastic Asphalt (SMA)

Mix designation	Stone mastic asphalt	
Grading	1	2
Nominal aggregat size	13 mm	10 mm
Nominal layer thickness	40-45 mm	30-35 mm
IS Sieve (mm)[1]	Cumulative % by weight of total aggregate passing	
16.0	100	
13.2	90-100	100
9.5	54-70	90-100
4.75	26-39	30-50
2.36	21-28	21-28
1.18	17-25	16-25
0.6	15-22	14-22
0.3	13-19	12-20
0.15	9-15	10-17
0.075	8-13	9-13
Bitumen content per cent mass of total mixture[2]	6.5-7.5	7-7.5
Bitumen grade (pen)	S 65 or S 55	S 65 or S 55

Notes: [1]The aggregate grading shall not vary from the low limit on one sieve to the high limit on the adjacent sieve.
[2]Determined in accordance with para 4.3.11.4.

4.3.11.4. Mix design : The mix is designed in the laboratory by preparing specimens as per the Marshall Method. It may be noted that for SMA, the Marshall stability and flow values may be misleading and are not suitable for evaluation of a job mix formula for SMA. The loose mixture and compacted . specimens should comply with the requirements of binder content and air voids as per paras 4.3.11.5 and 4.3.11.6.

4.3.11.5. Binder content : When tested at the target composition, the loose mixture should demonstrate not more than 0.3 per cent mortar drainage, by total mass of mixture, at a temperature of 175°C. The test shall be carried out using the apparatus and general principles stated in ***Appendix 6.*** The drainage shall be calculated as:

$$\text{Mortar drainage} = [(W_2 - W_i)/(1100 + B + X)] \times 100 \text{ per cent}$$

where B is the initial mass of binder in the mixture, X is the initial mass of fibres in the mixture (if used), W_1 and W_2 are the mass of tray and foil before testing and tray and foil with drained mortar after testing respectively.

4.3.11.6. Air voids : Three compacted specimens should be manufactured at the target composition and the air void contents of these should be measured by the procedure described in ASTM D3203 using:

(a) the maximum density of the mixture, obtained using the theoretical maximum specific gravity of the loose mixture, determined in accordance with ASTM D2041 and converted to relative density using the appropriate correction factor;

(b) the bulk density of the specimen, determined in accordance with BS:598, Part 104: Clause 4, as the bulk density required by ASTM D3203.

At the target composition, the air void content of the mixture shall be within the range 2-4 per cent.

4.3.12. Bituminous cold mix (including gravel emulsion) : designed cold mix (Clause 519 of Ministry's Specifications)

4.3.12.1. Description : Bituminous Cold Mix consists of unheated aggregate and emulsified or cutback bitumen. Two types of mixes are considered, namely Designed Cold Mix and Recipe Cold Mix. Either procedure is suitable for gravel emulsion mixtures, but the design procedure is preferred. The Designed Mix procedure should be used unless the Recipe Mix procedure is specifically approved by the Engineer.

4.3.12.2. Use : Bituminous Cold Mixes are used in situations where hot-mix plants are not readily available, including for work in remote areas and maintenance operations.

4.3.12.3. Materials

(A) **Aggregates:** The aggregates should comply with the physical requirements as given in para 4.3.4.3 (A). If there is a coating problem with anionic emulsion or cutback, hydrated lime or anti-strip additive (details in Appendix-1) may be added in small amount, determined by trial and error to meet the requirements, or a change to cationic emulsion should be tried.

The combined aggregate for the particular mixture should fall within the limits given in Table 4.24.

Table 4.24. Guide to Aggregate Grading and Bitumen Content

Nominal Maximum Size (mm)	9.5	13.2	19.0	26.5
Allowable Thickness (mm)	25-35	36-50	51-75	76-100
IS Sieve (mm)	Cumulative per cent by weight of total aggregate passing			
37.5	- -	- -	- -	100
26.5	- -	- -	100	90-100
19.0	- -	100	90-100	- -
13.2	100	90-100	--	56-80
9.5	90-100	- -	60-80	- -
4.75	60-80	45-70	35-65	29-59
2.36	35-65	25-55	20-50	19-45
0.30	6-25	5-20	3-20	5-17
0.075	2-10	2-9	2-8	1-7
Guide to bitumen content, per cent by weight of total mixture[1]				
Cutback	Minimum 4 to Maximum 6			
Emulsion	Minimum 7 to Maximum 10			

[1] To be determined by the modified Marshall Test.

Table 4.25. Guide for Uses of Bitumen in Cold Mix

Type of Construction	Emulsified Bitumen									Cutback Bitumen						
	Anionic				Cationic					Medium Curing (MC)				Slow Curing (SC)		
Cold-laid Plant Mix Pavement Base and Surfaces	MS-2 HFMS-2	MS-2h HFMS-2h	HF MS-2s	SS-1	SS-1h	CMS-2	CMS-2h	CSS-1	CSS-1h	70	250	800	3000	250	800	3000
Open-graded Aggregate	X	X				X	X									
Well-Graded Aggregate			X	X	X			X	X		X	X	X	X	X	X
Patching, Immediate Use				X	X			X	X		X	X			X	
Patching Stockpile											X	X		X	X	

(B) **Binder:** The binder should be a bituminous emulsion as specified in AASHTO M140 (ASTM D977) or AASHTO M208 (ASTM D2397), namely, MS-2, MS-2h, HFMS-2, HFMS-2h, HFMS-2s, SS-1, SS-1h, CMS-2, CMS-2h, CSS-1 and CSS-1h. Alternatively, a cutback bitumen as specified in AASHTO M82 (ASTM D 2027) or ASTM D2026, namely MC-70, 250, 800 & 3000 and SC-250, 800 and 3000 may be used. If approved by the Engineer, an equivalent material which conforms with IS:8887 or IS:217, may be used.

A general guide for the use of these binders is given in Table 4.25, but the final selection should be made after laboratory evaluation with the aggregates to be used. The binder with the highest residual viscosity at ambient temperatures that can reasonably be handled by the mixing and laying equipment proposed should be used.

4.3.12.4. Mixture design : Apart from the conformity with the grading and quality requirements for individual ingredients, the mixture should meet the requirements set out in Table 4.26.

4.3.12.5. Binder content : The binder content should be optimised to achieve the requirements of the mixture set out in Table 4.26. The method adopted should be that described in Appendix F and H of the Asphalt Institute's Manual MS-14.

Table 4.26. Mixture Requirements for Designed Cold Mix

Parameter	Emulsion[1]	Cutback[2]
Minimum Stability (kN at 22°C) Emulsion	2.2 for paving	2.2 for maintenance
(kN at 25°C) Cutback		3.3 for paving
Per cent maximum stability loss on soaking	50[3]	25[4]
Minimum flow (mm)	2	2
Compaction level (number of blows)	50 blows on each of the two faces	75 blows on each of the two faces
Per cent air voids	3-5[5]	3-5
Per cent voids in mineral aggregate (VMA)	See Table 4.27	
Per cent minimum coating[6]	50	-

Notes:

1. Using "Marshall method for emulsified asphalt-aggregate cold mixture design", Appendix F, MS-14.
2. Using "Marshall method for cutback asphalt-aggregate cold mixture design", Appendix H, MS-14.
3. With vacuum saturation and immersion.
4. Four days soak at 25°C.
5. Refers to total voids in the mix occupied by air and water.
6. Coating Test, Appendix F, MS-14.

Table 4.27. Minimum Per cent Voids in Mineral Aggregate (VMA)

Nominal Maximum Particle Size IS Sieve (mm)	Minimum VMA (per cent)
9.5	16.0
12.5	15.0
19.0	14.0
25.0	13.0
37.5	12.0

4.3.12.6. Job mix formula : The job mix formula proposed for use in the works should give the following details:

(i) Source and location of all materials;

(ii) Proportions of all materials expressed as follows where each is applicable;

   (a) Binder as percentage by weight of total mixture;

(b) Coarse aggregate/fine aggregate as percentage by weight of total aggregate;

(iii) A single definite percentage passing each sieve for the mixed aggregate;

(iv) The results of tests enumerated in Table 4.26 as obtained by the Contractor;

(v) Test results of the physical characteristics of the aggregates to be used;

(vi). Spraying temperature of binder if appropriate.

While working out the job mix formula, it must be ensured that it is based on a correct and truly representative sample of the materials that will actually be used in the work and that the mixture and its different ingredients satisfy the physical and strength requirements.

Should a change in the source of materials be proposed, a new job mix formula should be established before actually using the materials.

4.3.12.7. Permissible variation from the job mix formula : The permissible variations of the individual percentages of the various ingredients in the actual mix from the job mix formula to be used, should be within the limits as given in Table 4.28. These variations are intended to apply to individual specimens taken for quality control tests in accordance with Chapter 10.

Table 4.28. Permissible Variations from the Job Mix Formula

Description	Permissible variation	
	Base/binder course	Wearing course
Aggregate passing 19 mm sieve or larger	± 8 per cent	± 7 per tent
Aggregate passing 13.2 mm, 9.5 mm	± 7 per cent	± 6 per cent
Aggregate passing 4.75 mm	6 per cent	± 5 per cent
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	± 5 per cent	± 4 per cent
Aggregate passing 0.3 mm, .0.15 mm	± 4 per cent	± 3 per cent
Aggregate passing 0.075 mm	± 2 per cent	± 1.5 per cent
Binder content	± 0.3 per cent	± 0.3 per cent

4.3.13. Bituminous cold mix (including gravel emulsion) : recipe cold mix (Clause 519 of Ministry's Specifications)

4.3.13.1. Description : These are premixes made with emulsion binder which are laid immediately after mixing and while the emulsion is still substantially in an unbroken state.

4.3.13.2. Use : These mixtures are considered suitable for use only for emergency and minor repair work and temporary road surface improvement.

4.3.13.3. Materials

(A) **Binder:** Emulsions of sufficient stability for mixing with the particular graded aggregate should be used. Grades of emulsion quoted are in accordance with BS:434, Part-1-1984 but comparable grades to IS or AASHTO specifications may be used. Guidance on selection of an appropriate grade of emulsion is given in para 2.4.3.

(B) **Aggregates:** Any normal, clean, but not necessarily dry, aggregate can be used, provided that it has sufficiently high crushing strength with regard to the traffic to be carried. Typical gradings are given in Table 4.29.

4.3.13.4. Aggregate grading and binder content : When tested in accordance with IS:2386, Part I (wet-sieving method), the combined aggregate grading for the particular mixture should fall within the limits shown in Table 4.29. The grade and range of quantity of emulsion are also indicated in this Table. The actual quantity of emulsion to be used should be based on the results of trial mixes made in the laboratory.

Table 4.29. Composition of Recipe Mixes

Nominal Size (mm) and Type of Macadam	40 Single Course	40 Open textured base course	14 Open textured wearing course	6 Medium textured wearing couse	- - Fine coated
Allowable Thickness (mm)	75-100	75-100	31-50	21-30	15-20
IS sieve Size (mm)	Cumulative per cent by weight of total aggregate passing				
45	100	100	--	--	--
37.5	90-100	90-100	--	--	--
26.5	55-90	55-85	--	--	--
19	--	--	100	--	--
13.2	35-55	15-35	90-100	--	--
9.5	--	--	55-75	100	--
6.3	20-30	--	25-45	90-100	100
3.35	10-20	0-10	15-25	45-65	--
2.36	--	--	--	--	75-100
1.18	--	--	--	10-30	--
0.60	--	--	--	--	30-55
0.30	2-10	--	--	--	--
0.15	--	--	--	--	10-25
0.075	--	--	2-6	2-8	5-15
Emulsion grade and quantity					
Generally	A2-57[4]		or	A2-50[4]	
Under some circumstances	--	--	--	A3	A3
Quantity(1) liters/tonne	55 to 70	45 to 65	70 to 90	85 100	100 (2)(3) 120

Note:

[1] For pricing purposes the lower quantity in these ranges should be assumed.

[2] With coarser grading quantity may sometimes be reduced to 80 litres/tonne and with finer grading it may sometimes be increased upto 135 litres/tonne.

[3] Use 0-70 litres/tonne of water as necessary.

[4] A2-50 and A-57 are British grades of emulsion and their grading system is explained in para 2.2.3, Chapter 2.

4.3.14. Sand asphalt base course (Clause 520 of Ministry's Specifications)

4.3.14.1. Description : Sand Asphalt Base Course is composed of a mixture of sand, mineral filler where required and bituminous binder, placed and compacted upon a prepared and accepted subgrade.

4.3.14.2. Use : Sand Asphalt Base Course is used in special situations, like, quality coarse aggregates not being available within economical leads and/or water needed for conventional base course construction not being readily available, as in desert areas.

4.3.14.3. Materials

(A) **Sand:** Should be clean, naturally occurring or blended material free from any deleterious substances, well graded within the limits given in Table 4.30 and with other physical properties conforming to the requirements of this table.

(B) **Filler:** When required should consist of finely divided mineral matter, such as, rock dust, hydrated lime or cement. The filler should conform to the grading given in para 4.3.2.3 (C)

(C) **Bitumen:** The bitumen should be paving bitumen of penetration grade S65 or S90 as per IS:73. Guidance on selection of an appropriate grade is given in para 2.4.1.

Table 4.30. Sand Grading and Physical Requirements for Use in Sand Asphalt Base Course

IS Sieve (mm)	Cumulative percentage passing by weight of total aggregates
9.5	100
4.75	85-100
2.36	80-100
1.18	70-98
0.60	55-95
0.30	30-75
0.15	10-40
0.075	4-10
Plasticity Index per cent	6 max
Sand Equivalent (IS:2720, Pt. 37)	30 min
Los Angles Abrasion Value of fraction retained on 4.75 mm sieve (IS:2386, Part 4)	40 max

Note: Maximum thickness for sand asphalt is 80 mm.

4.3.14.4. Mix design : Apart from conformity with the grading and quality requirements for individual ingredients, the mixture should meet the requirements set out in Table 4.31. The binder content should be optimised to achieve the requirements of the mixture set out in Table 4.31. The Marshall method for determining the optimum binder content should be adopted as described in the Asphalt Institute Manual MS-2,

Table 4.31. Requirements for Sand Asphalt Base Course

Parameter	Requirement
Minimum stability (KN at 60°C)	2.0
Minimum Flow (mm)	2
Compaction Level (No. of blows)	75 blows on each of the two faces
Per cent air voids	3-5
Per cent voids in mineral aggregates (VMA)	>16
Per cent voids filled with bitumen (VFB)	65-75

4.3.15. High performance base (New Specification)

4.3.15.1. Description : High performance base is an improved bituminous paving mixture for the main structural layer of the pavement. Its design is based on assessment of the effect of variations in aggregate grading, binder content and level of compaction on those mechanical properties of the mixture, which relate to its performance in the pavement.

4.3.15.2. Use : High performance base is used on heavily trafficked roads. Since its design procedure measures performance-based mechanical properties, it permits the bituminous pavement thickness design to be optimised for the particular situation of traffic and climate. Because of the main emphasis on performance of the final product rather than the recipe of mixture ingredients, it lends itself to the optimum use of locally available materials.

4.3.15.3. Materials

(A) Aggregates: The coarse aggregates, fine aggregates and mineral filler should conform to the physical requirements given in 4.3.4.3(A). Alternative materials may be considered if they meet the volumetric and mechanical property requirements.

The maximum aggregate size and filler content should be 37.5 mm and 5 to 10 per cent respectively. The target grading may be calculated using the following equation, developed on the basis of field experience;

$$P = \frac{(100-F)(d^n - 0.075^n)}{(D^n - 0.075^n)} + F$$

where P = percentage passing a sieve of aperture size d mm
D = maximum nominal aggregate size in mm
F = filler content (per cent)
n = an exponent, between 0 and 1.

The filler content F should be between 5 and 10 per cent; typically a value of 6 per cent is used.

The value of n should be at least 0.5 to ensure that the target grading is coarser than the maximum density grading so as to avoid a mixture, which could potentially be compacted to too low a void content which may not have adequate resistance to permanent deformation. Values of n greater than 0.7, on the other hand will be prone to segregation. A minimum of three gradings with different values of n should be selected.

(B) **Binder:** The binder should be either a penetration grade bitumen meeting the requirements of IS:73 or a base penetration bitumen to which a "modifier" has been added to or blended with. Guidance in this regard is given in para 2.4.

4.3.15.4. Mixture design : The procedure (flow chart shown in Fig. 4.1) involves the following four steps:

(A) **Selection of aggregate grading and target binder content:** For each of the three gradings selected as mentioned in para 4.3.15.3 (A), specimens should be prepared in accordance with the general requirements of the Marshall method described in Asphalt Institute Manual MS-2, using 75 blow compaction and'a range of binder contents to encompass at least those yielding an air void content of 4±2. For selection of the optimum grading and target binder content, the key parameters listed in Table 4.32 should be considered. The Marshall stability and flow testing are not required for this evaluation.

Table 4.32. Key Volumetric Requirements for High Performance Base

Parameter	Requirement
Per cent air voids (V_A)	3-5
Per cent voids in mineral aggregate (VMA)	See Table 4.12
Per cent voids filled with bitumen (VFB)	65 - 75

Selection of the preferred grading and target binder content should be based on that which most satisfactorily meets the established criteria. While guidance for selection is given in ***Appendix-7***, the key points are summarised below:

- The VMA should be slightly to the left ("dry") side of the VMA/binder content curve and gradings which fall below the minimum values in Table 4.12 at any binder content should not be selected.
- The design range of air voids (3-5 per cent) is the ultimate level to be achieved in the field after several years of traffic. The ideal per cent air voids just after construction is thus about 8 per cent. Mixtures which ultimately compact to less than 3 per cent air voids in the field are likely to be susceptible to permanent deformation, while mixtures with initial air voids greater than 8 per cent may lead to greater binder oxidation, ageing and/or an increased probability of water damage. High air voids may also be associated with deformation.
- Use of the VFB criterion helps to prevent. the design of mixtures with marginally acceptable VMA and also restricts the allowable air voids for mixtures near the minimum VMA.

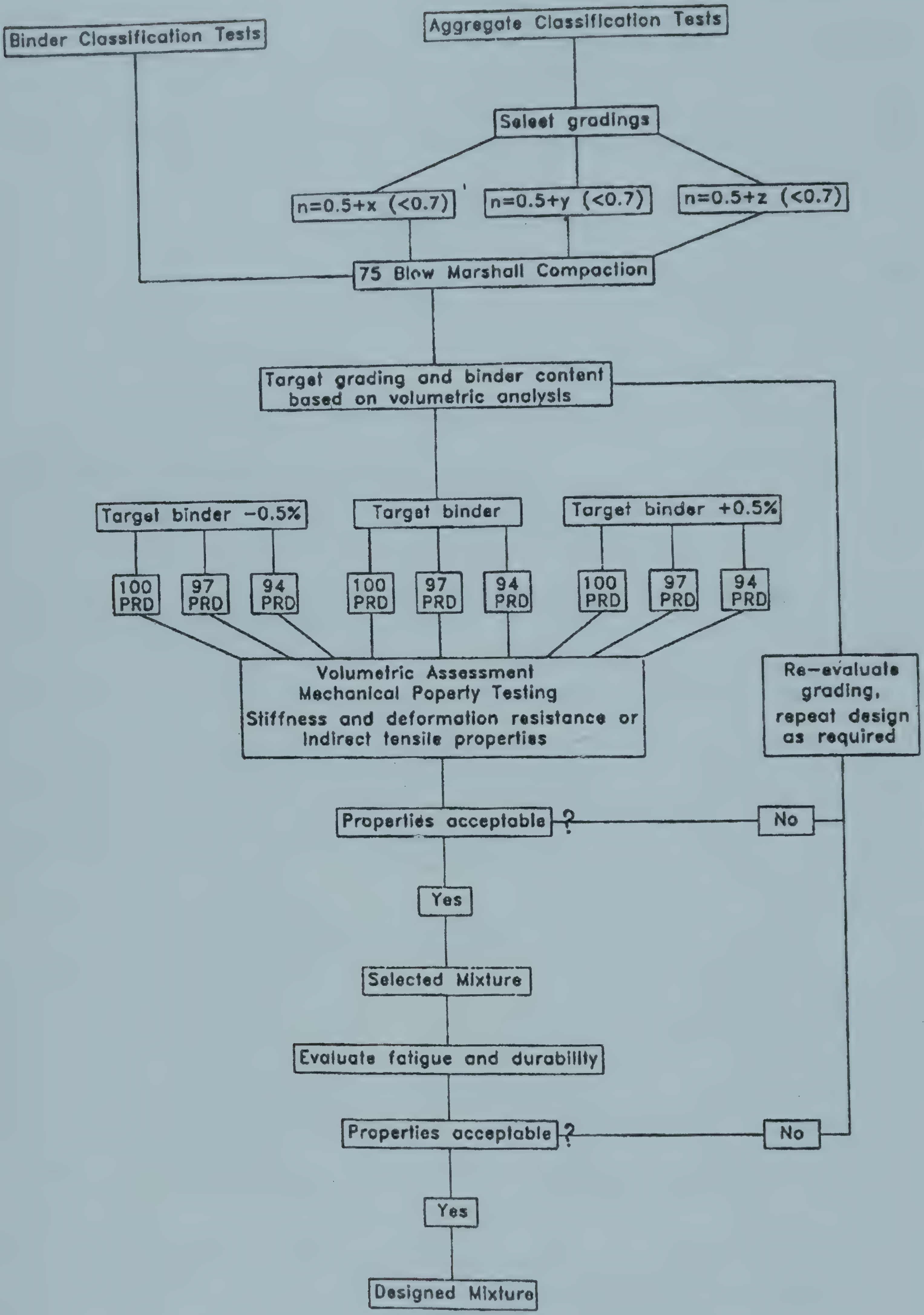

Binder Classification Tests
Aggregate Classification Tests
Select gradings
n=0.5+x (<0.7)
n=0.5+y (<0.7)
n=0.5+z (<0.7)
75 Blow Marshall Compaction
Target grading and binder content based on volumetric analysis
Target binder −0.5%
Target binder
Target binder +0.5%
100 PRD
97 PRD
94 PRD
100 PRD
97 PRD
94 PRD
100 PRD
97 PRD
94 PRD
Volumetric Assessment
Mechanical Poperty Testing
Stiffness and deformation resistance or Indirect tensile properties
Re-evaluate grading, repeat design as required
Properties acceptable?
No
Yes
Selected Mixture
Evaluate fatigue and durability
Properties acceptable?
No
Yes
Designed Mixture

Fig. 4.1. Flow Chart for Evaluation of High Performance Base

- At the same binder content, air voids and VMA decrease With increasing compactive effort and the binder content at minimum VMA shifts. It is important, therefore, to ensure that the compactive effort, which is selected, simulates that expected from the design traffic.
- The grading and binder content selected should be those, which best fit, these criteria and are least sensitive to small variations in binder content. The influence of the pavement structure in which the high performance base will be ncorporated should also be considered, particularly the specific project conditions of traffic and climate. Thus, mixtures with binder contents on the high side of the range are likely to be less susceptible to cracking because of the additional flexibility, whereas mixtures on the low side of the range are likely to be less susceptible to rutting.

(B) **Compaction level and binder content:** Having selected the target grading and binder content (as in the previous paragraph), the effects of variations of binder content above and below the target value must be investigated at three levels of compaction. These must be chosen to encompass the expected production tolerances for binder content and to reflect states at, above and below the level of compaction likely to be achieved in the field.

The protocols to be followed for the production of laboratory mixtures for the evaluation of variation of compaction level and binder content are given in ***Appendix-8***. The choice of compaction method lies with the contractor, but it should be recognised that different compaction methods may give differences in mechanical properties for the same material, particularly in respect of resistance to permanent deformation. It is known that the mechanical properties of specimens manufactured by Marshall method of compaction, in particular, are not representative of those determined on field compacted specimens, and Marshall compaction is not, therefore, recommended. At the present time, apparatus used for the Percentage Refusal Density (PRD) test is recommended as a suitable means of achieving the required levels of compaction. Guidance on the use of the procedure as given in A***ppendix-5*** may be achieved in the manner described below.

(i) Compaction to refusal (100 PRD), i.e., 2 minutes compaction on each face of the specimen with the vibrating hammer. Material temperature = 160°C.

(ii) Intermediate level of compaction, i.e., 1 minute compaction on each face of the specimen. Material temperature = 100°C (About 97 PRD).

(iii) Low level of compaction, i.e., 30 seconds compaction on each face of the specimen. Material temperature = 90°C (about 94 PRD).

The dimensions of the moulded specimens should be 152 mm in diameter by approximately 100 mm in height.

After cooling and demoulding, a 100 mm diameter core should be cut from each specimen, the core then being trimmed to a length of about 70 mm using a diamond tipped masonry saw.

The recommended binder contents for this assessment are the target value determined and values 0:5 per cent above and below. Triplicate specimens should be made at each binder content and each level of compaction, resulting in 27 specimens.

(C) **Selection of the designed mixture:** For the determination of the volumetric properties of the samples prepared as in (B) above, the following measurements should be made to enable the air void contents of the samples to be determined in accordance with ASTM D3203 :

(i) The maximum density of the mixture, obtained using the theoretical maximum specific gravity of the loose mixture, determined in accordance with ASTM D2041 and converted to relative density using the appropriate correction factor.

(ii) The bulk density of the specimens, determined in accordance with BS:598, Part 104 Clause 4, as the bulk density required by ASTM D3203, except that the specimens should be coated with self-adhesive aluminium foil rather than the wax specified in the British Standard when weighing the specimens in water.

(iii) The determined air voids at refusal density and at 94 and 97 PRD should be evaluated in the light of the requirement for an absolute minimum air voids at refusal of 1 per cent and the considerations enumerated in the preceding pars above.

Depending on the specific demands of the site, minimum air voids at refusal may need to be increased to 2 per cent (fast moving heavy traffic) or 3 per cent (slow moving heavy traffic, high axle loads). Acceptable ranges for void content and VMA with a cut-off for binder volume of 8 per cent are shown in ***Appendix-9*** for air voids at refusal of 1,2 and 3 per cent. The volumetric screening described enables the rejection of unsuitable screening formulations before mechanical testing is carried out.

All formulations which pass the volumetric screening are then subjected to mechanical property testing. Two procedures are permitted. Procedure A should ordinarily be used, unless otherwise instructed.

Procedure A: The stiffness of each specimen should be determined using the Indirect Tensile Stiffness Modulus (ITSM) test at 20°C in accordance with BSDD 213. The deformation resistance of each specimen should be determined in accordance with the Repeated Load Axial Test (RLAT) described in BS DD 226, under the standard conditions of 40°C temperature, 100 kPa axial load and 2 hour test duration. The ITSM test is non-destructive. The principle of each test procedure is described in ***Appendix-10***.

The criteria of acceptance will depend upon the specific circumstances of the pavement structure and the traffic and climate to which it will be exposed, subject to the following minimum threshold values.

- Stiffness (ITSM) not less than 2000 MPa at 20°C
- Deformation resistance (RLAT) at 40°C and greater than 2 per cent cumulative permanent strain at the end of the test.

Procedure B : A simple modification to the Marshall test may be used. This involves application of the load through 10 mm wide strip loading platens as described in ASTM D4867, so that the indirect tensile (splitting) strength can be determined. This procedure should be carried out on the specimens prepared as described in the preceding para above. Two parameters are required for evaluation.

- The indirect tensile strength in MPa
- The area under the load/time curve in kNs.

The procedure is detailed in ***Appendix-11***. The optimum mixture combination will be that which best satisfies the requirements of maximum load and maximum area under the load/time curve. The latter can be thought of as the "energy dissipated" during failure and larger values may, thus be, associated with higher crack resistance. The following minimum values should be achieved:

- Indirect tensile strength, not less than 2.0 MPa at 4°C.
- Area under load/time curve, not less than 50 kNs at 40°C.

4.3.15.5. Verification of the Designed Mixture : Having selected the optimum design mixture on the basis of a consideration of mixture volumetrics and stiffness and deformation resistance for indirect tensile strength, the durability (water sensitivity) of the designed mixture should be assessed using the procedure described in AASHTO T283. The minimum retained tensile strength should be 80 per cent.

Where the specialised testing equipment described earlier is available, the fatigue resistance of the designed mixture can be evaluated using the Indirect Tensile Fatigue Test (ITFT). Ten additional specimens should be prepared as described earlier at the 97 PRD level of compaction, and the compacted specimens oven aged (120 hours at 85°C) to simulate in-service conditions. The ITFT should then be carried out on this additional set of samples. The procedure for the oven ageing and for the ITFT are described in ***Appendix-12***. The requirements for fatigue resistance will be pavement specific, subject to the following minimum threshold criterion :

- Minimum ITFT life at 100 microstrain, 3,50,000 cycles. Provided all the design criteria are met on the selected mixture, this becomes the design mixture. As indicated in Fig. 4.1, if at any stage in the procedure the required design criteria are not met, the mixture design must be repeated with appropriate modifications.

4.3.16. Modified binder - emerging materials (Clause 521 of Ministry's Specifications)

4.3.16.1. Description : For use in high quality bituminous courses, emerging materials of the following generic class are considered:

- Rubberised Bitumen/Polymer Modified Bitumen
- Fibres

4.3.16.2. Use/Purpose : The use of these materials is expected to result in an extended service life of bituminous pavements subjected to heavy traffic loads and in extreme climatic conditions, thus justifying the extra cost of adding modifiers/fibres. Other advantages include: lower temperature susceptibility; higher resistance to ageing; higher fatigue life; higher resistance to cracking and better adhesion between aggregates and binder.

4.3.16.3. Rubberised bitumen/polymer modified bitumen : The base binder should conform to IS:73, prepared by incorporating any of the following types of modifiers:

(i)	Plastics:	Thermoplastics; Thermosets
(ii)	Elastomers:	Natural Rubber; Synthetic Elastomers
(iii)	Reclaimed Rubbers	

Bitumen modifiers should : (a) be compatible with bitumen, (b) resist degradation of bitumen at mixing temperature, (c) be capable of being processed by conventional mixing and laying machinery, (d) produce coating viscosity at application temperature, (e) maintain premium properties during storage, application and in-service, and (f) be cost effective on a life-cycle-cost basis.

Detailed information on the use of polymer modified binder are available in IRC:.SP:53. A number of proprietary products are now available in the Indian market. For such proprietary products, test reports and cost effectiveness should be the basis for their selection in road works. The quantity of modifier to be added should be determined by tests on bitumen, modified bitumen and on bituminous mixes and the extent of improvements in the properties of paving mixes as desired. Indicative doses of some of the common modifiers are given in Table 4.33.

Table 4.33. Type of Additives for Bitumen Modification and their Indicative Doses

Sl. No.	Type of Modifier	Examples	Indicative Dose Level, per cent by wt. of bitumen
1.	Plastics		3-6
	Thermoplastics	Low Density Polyethylene (LDPE), Ethylene Vinyl Acetate (EVA), Ethylene Butyl Acrylate (EBA) Epoxy Resins	
	Thermosets	Epoxy Resins	3-5
2.	Elastomers		
	Natural Rubber	Latex or Dry Rubber Powder	2-4
	Synthetic Elastomers	Styrene Butadiene Styrene Block Copolymer (SBS), Styrene Butadiene Rubber (SBR)	3-5
3.	Reclaimed Rubbers	Tyre Crumb Rubber Powder from discarded truck tyres further improved by additives	10-12

The choice of grade of a modified bitumen should be based on the minimum and maximum atmospheric temperatures in the region as per Table 4.34. For cold climatic areas, properties, viz, penetration at 4°C and Fraass breaking point values should be taken into account.

Table 4.34. Selection Criteria for PMB and CRMB Based on Atmospheric Temperature

		Maximum Atmospheric Temperature °C		
		< 30	30 to 40	> 40
Minimum Atmospheric Temperature, °C	< - 15	PMB - 120 CRMB - 50	PMB - 70 CRMB - 55	PMB - 70 CRMB - 60
	15 to -15	PMB - 120 CRMB - 55	PMB - 70 CRMB - 55	PMB - 40 CRMB - 60
	> 15	PMB - 70 CRMB - 55	PMB - 40 CRMB - 60	PMB - 40 CRMB - 60

PMB - Polymer Modified Bitumen
CRMB - Crumb Rubber Modified Bitumen

Pre-blended modified binders that are claimed to remain homogenous in storage should be tested for storage stability prior to the start of the work in accordance with ***Appendix-13***. The mean of the differences in softening point, top to bottom, of not less than three pairs of samples should not exceed 5°C. Pre-blended modified binders claimed to remain homogeneous that fail to meet this requirement and all other pre-blended modified binders should be stored in accordance with a quality control procedure which follows the manufacturer's instructions detailing the mode of circulation or agitation in the tank storage necessary to ensure homogeneity is maintained. In addition, all pre-blended modified binders should meet the original specification for softening point and penetration for the binder after the 7 days storage period described in ***Appendix-13***. If binder modifiers are partially insoluble when analysis is carried out to determine the soluble binder content in accordance with ASTM D2172 using either of the methods, then test results should be submitted that:

(i) Establish the degree of insolubility of the modifier; and
(ii) Determine the adjustments to the measured soluble binder content that will be necessary.

If required, analysis of the polymer content of polymer modified material should be carried out in accordance with a method recommended by the polymer supplier or other agreed analysis method.

Prior to their use, modifiers should have proved satisfactory under similar circumstances elsewhere or should have undergone appropriate performance trials.

In the absence of adequate evidence of this kind a trial should be undertaken to demonstrate the suitability of the modifier.

4.3.16.4. Blending of modifier with bitumen : The method of blending the modifier with bitumen in the field should be such as to produce a homogenous material. A high speed agitator operated by an electric motor should be used for the purpose. The blending should be continued for sufficient time so as to result in a homogenous mass.

4.3.16.5. Fibres : Fibres that are incorporated in a bituminous binder should be glass-fibre, polypropylene fibre or any other similar material. The suitability of the material for improving the properties of the bituminous mixture after conducting tests with and without fibres, should be demonstrated.

Proposals to use a fibre in a bituminous mixture should be substantiated, complete with all details including test results, manufacturer's recommendations for addition or means of incorporating the fibres, homogeneously, without segregation, into the mixture.

Before agreeing to the use of a fibre, it should have been proved to be satisfactory in use under circumstances, similar to the work, elsewhere or it would have undergone appropriate performance trials. Documented evidence of use and trials of the fibre, in any country having conditions similar to India will be acceptable.

Where information on use or trials is inadequate or lacking, trials may be required to be undertaken before agreeing to the use of the fibre.

The use of polypropylene fibres should be restricted to mixing temperatures below 140°C.

4. 3.17. Micro asphalt concrete (MAC) resurfacing (New Specification)

4.3.17.1. Description : Micro Asphalt Concrete (MAC) Resurfacing is a mixture of well-graded fine aggregates of 6 mm to 12 mm down @ 8 to 14 kg per sqm; cationic polymer modified bituminous emulsion @ 11 to 13 per cent mixed with water @ 10 to 15 per cent and Portland cement filler @ 0.5 to 2 per cent (all by weight of aggregates). The mix is controlled in the field by kg/m^2 and not by mm thickness. Generally laid in a single layer, but when the existing surface is polished, highly deformed or cracked, it is advisable to apply in two layers.

4.3.17.2. Use/ Purpose : MAC is applied on existing pavement surfaces which are structurally adequate but the surface shows signs of premature ageing, aggregate loss, cracking, high degree of polishing etc. and where conventional surface dressing, slurry sealing etc. prove to be inadequate. It may also be used when the nature of pavement (cement concrete or stone set paving blocks) and/or construction constraints (limited height of kerb gullies, manhole covers etc.) make other solutions extremely expensive.

4. 3.17.3. Materials

(A) **Aggregate:** Quality aggregate satisfying the requirements for use in bituminous concrete except that the Los Angeles Abrasion Value should be less than 25 and the accelerated polishing co-efficient (as per BS:812/ASTM E303) should be greater than 0.45. Depending on the thickness of the overlay to be made and the texture required, the following aggregate gradations are used :

Sieve Size (mm)	Per cent Passing		
	I	II	III
12.5			100
10.0		100	85-100
6.3	100	80-100	70-90
5	85-100	70-90	60-85
2.5	65-90	45-70	40-60
1.25	45-70	28-50	28-45
0.63	30-50	18-33	18-33
0.32	18-35	12-25	11-25
0.16	10-25	7-17	6-15
0.08	7-15	5-10	4-8

Fine gradations are used on aged or cracked surface, thus restoring their waterproofing characteristics. On skidding pavements, coarser gradations will provide a good anti-skidding surface.

(B) **Bituminous emulsion:** The bituminous emulsion used is a controlled setting cationic one, modified by incorporating polymer in the emulsion. The polymer can be added by any of the following two methods :

(i) Incorporating in the water phase (by mixing a latex into the water phase).
(ii) Adding to the bitumen (i.e., blending the polymer with the bitumen).

In both cases, the polymer is added before the emulsification. The base bitumen generally used is 80/100 penetration.

(C) **Filler:** Portland cement is generally used @ 0.5 to 2 per cent by weight of aggregate to regulate the setting and increase the final cohesion of the mixture.

(D) **Water:** The amount of water added is nearly equal to that of emulsion. It facilitates the mixing and spreading and is is later lost by evaporation.

(E) **Additive:** An additive, a complex chemical agent is added to control the setting speed, delaying it just enough to facilitate the correct mixing and spreading. It also improves the aggregate/ binder adhesion.

4.3.17.4. Mix design : At the optimum binder content, the Aggregate/Binder cohesion (as per ASTM D3910) shows values of 12 to 14 kg-cm after 15 minutes and values in excess of 20 kg-cm after 60 minutes. The average mix formula is the following (of total aggregate weight) :

Bituminous Emulsion : 11 to 13 per cent

Water : 10 to 12 per cent

Portland cement : 0.5 to 2 per cent

Additive : Varies according to the climate and gradation of aggregates

CHAPTER 5

FIELD INVESTIGATIONS

5.1. General

Requirements for bituminous road pavements can cover many developments, including new construction over a newly laid base course, construction over widened portions of an existing road pavement, as part of periodic maintenance measures or as part of a pavement rehabilitation programme. In each case, it is necessary that certain field investigations be carried out prior to the design and construction of a bituminous pavement layer. The different types of field investigations are broadly outlined in the succeeding paragraphs.

5.2 Types of Investigations

5.2.1. For new bituminous construction : The field investigations that need to be carried out for new bituminous construction works should, inter alia, cover the following aspects:-

- Topographic details
- Traffic Survey and analysis, which may also include axle-load surveys
- Environmental impact assessment and provision of mitigating measures
- Soil survey and survey for locally available road materials
- Pavement surface condition survey and road inventory for widening and strengthening projects
- Field studies for assessment of surface/subsurface drainage needs
- Socio-economic surveys surveys, where relevant

Appropriate design of any bituminous construction should take into consideration the availability and costs of the type and grade of straight-run bitumen, cutbacks and emulsions before incorporating them in the design , besides the different types of available coarse and fine aggregates.

In general, the various investigations covering the above-mentioned aspects should be carried out on the lines suggested in the "Guidelines for the design of Flexible pavements" (IRC:37), and the "Guidelines for Environmental impact Assessment of Highway projects" (IRC:104).

5.2.2. Investigations for maintenance and rehabilitation : For purposes of scientifically designing the required maintenance measures, the following are considered necessary:

(a) Visual rating
(b) Determination of riding quality
(c) Determination of skid resistance
(d) Structural evaluation of the pavement
(e) Existing pavement details
(f) Subgrade characteristics and strength

The above types of investigations are briefly outlined are briefly outlined below:-

5.2.2.1. Visual rating: This inspection is carried out by visually noting down the nature and extent of pavement distress. The usual manifestation of distress or damage occurs in the form of:

1. **Rutting** - The downwrd displacement of the road surface in relation to the remainder of the foad, usually in the wheel-tracks used by the bulk of the traffic in a particular lane. This may or may not be accompanied by shoving or any upward displacement of the road surface adjacent to the wheel-tracks. Rutting kay not in itself be diagnostic of a definite mode, and depth of the source of failure, but is usually considered in conclusion with other indications before a conclusion may be drawn. Typical rutting under wheel paths con be seen is Fig. 5.1

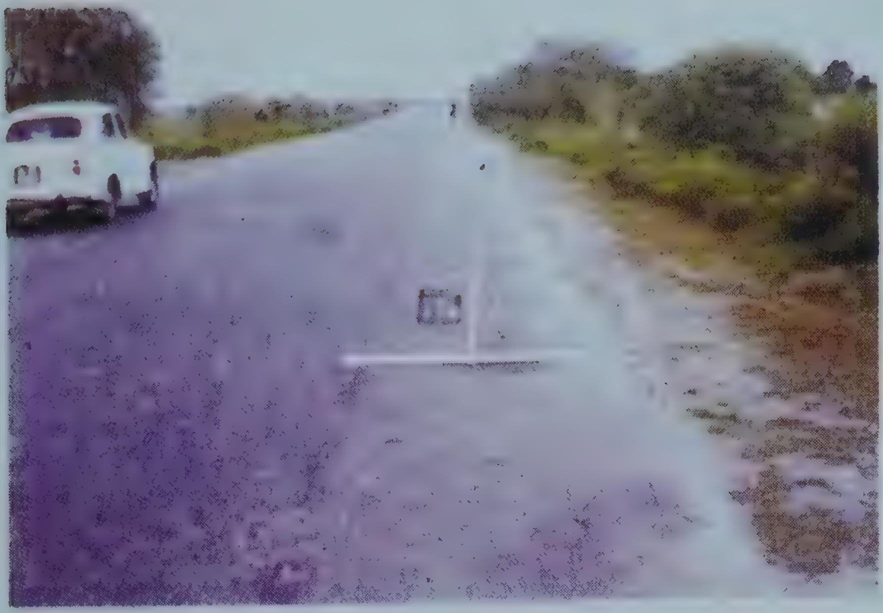


Fig. 5.1. Rutting

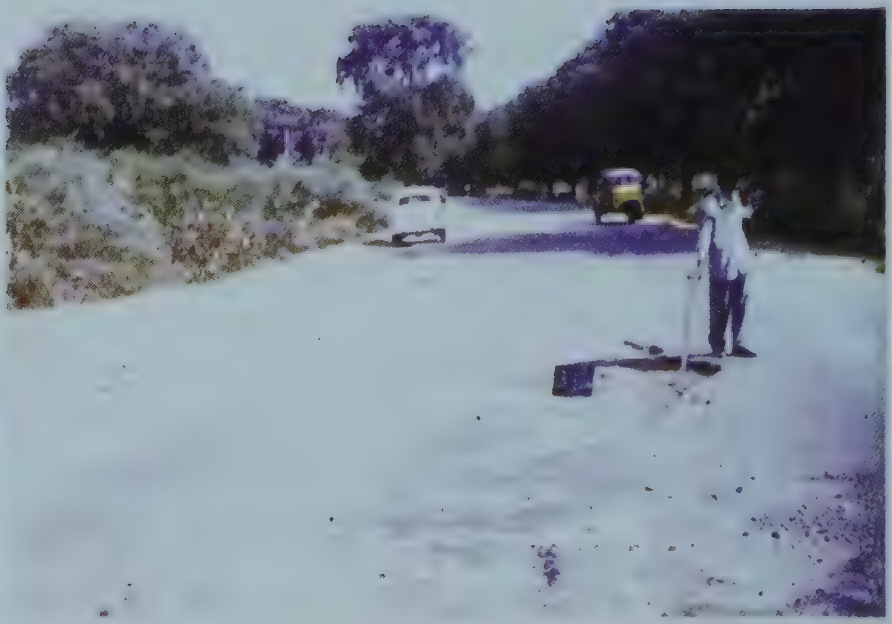


Fig 5.2. Ravelling

2. **Corrugations-** the appearance of small ridges and troughs in the road surface, generally at right angles to the direction of travel. While these are most commonly associated with gravel and earth roads, they do also occur in bituminous road surfaces. corrugations in bituminous road surfaces commonly indicate failure within the bituminous layers.

3. **Raveling-** the dislodging of individual pieces of aggregate from the surface of the road (Fig.5.2). In many instances. the loss of continuity of the surface caused by loss of aggregate, and the action of the loose aggregate already dislodged, under traffic, may accelerate further raveling. Raveling is often an indication of insufficient bitumen, inadequate adhesion between the bitumen and aggregate, or of age hardening of bitumen. A fog spray or resealing by the application of a slurry may treat it.

4. **Flushing-** (often referrd to as ("bleeding") - The collection, at the road surface, of excessive bitumen, giving a flat, smooth surface (Fig.5.3) with little or no protruding aggregate. Flushing can result in very poor skid resistance in wet conditions and, druing hot weather, may result in adhesion of the softened bitumen to the tyres of passing traffic.

5. **potholes -** the presence of holes in the road surface (Fig. 5.4.) These may result From mechanical damage to the road surface; they may be due to some in gerent defect in the road structure or lack of adequate surface drainage, or they may be at the manifestation of the start of the general breaking up of a section of the rod. The presence of other indicators (e.g., alligator cracking) may serve to distinguish the cause. It is, however, of vital importance, when repairing a pothole, to establish the cause of the failure and, especially the depth below the surface at which the failure occurred. when patching, the source of the failure must be removed and any poor or wet material replaced. Considerable sums of money are wasted throughout The world, everyyear, through failure to observe this basic requirement.

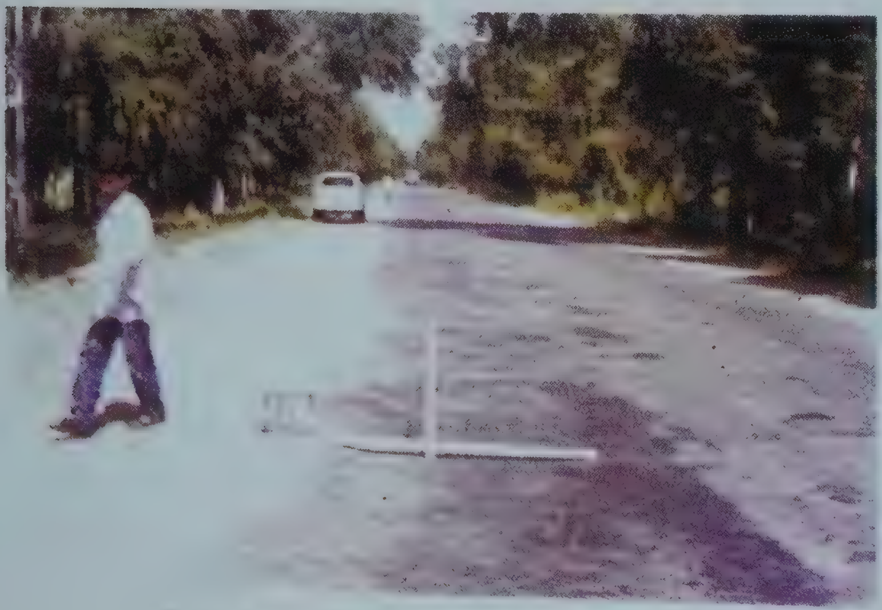


Fig. 5.3. Flushing and Bleeding

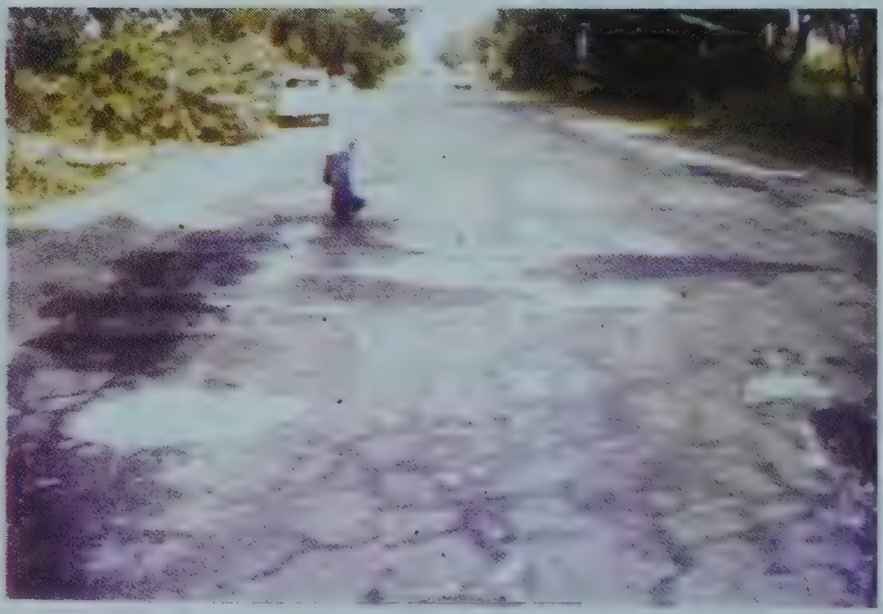


Fig. 5.4. Potholes

6. **Extent of existing patching-** repairs to previous failures (Fig. 5.5.) indicate that a problem occurred, but may not, in themselves, give many clues as to what the problem was. Investigation of the areas adjacent to existing patching may reveal more about whether the problem is continuing to manifest itself, and what it might be.
7. **Transverse cracking-** the presence of cracks, often well spaced, all or the majority of which are at right angles to the direction of travel. These are often associated with shrinkage of one or more of the upper pavement layers. this may be due to the presence of a cement stabilised pavement layer or to thermal movement. All cracks in the road surface, especially those located in high rainfall areas, should be sealed to prevent ingress of water.
8. **Longitudinal cracking** - the presence of cracks, generally oriented in the direction of travel of the traffic (Fig. 5.6.) These may result from a wide variety of causes. When associated with rutting, they may indicate the onset of failure of one or more of the pavement layers. when widely spaded, (and therefore sometimes referred to as "block cracking"), they may be associated with shrinkage. Block cracking (Fig. 5.7) in which the cracks occur more frequently (say at less than 2 metre intervals) may indicate the onset of a more serious failure.

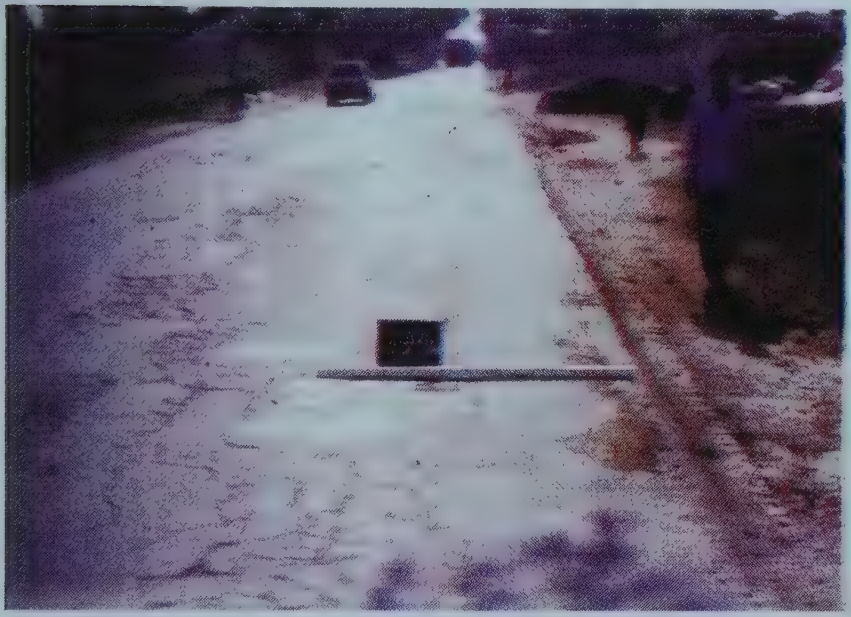


Fig. 55 Patching

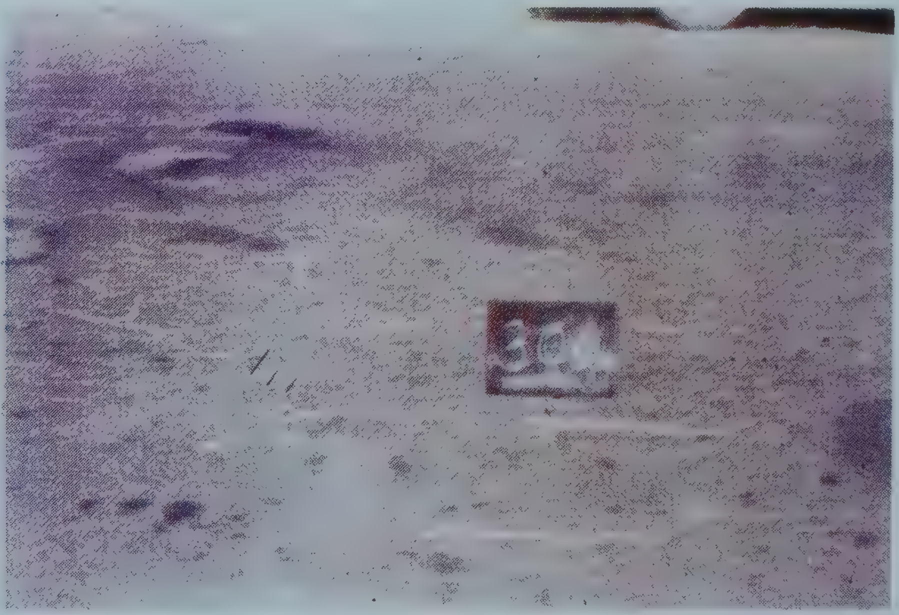


Fig. 5.6 Excessive Longitudinal and Transverse Cracking

9. **Alligator cracking** - known elsewhere as "crocodile cracking" , because the density and patterns of cracking is said to be reminiscent of the patterns seen on the backs of those animals. Alligator cracking (Fig.5.8) is usually an indication of a serious road failure, at a point at which it is usually too late in the cycle of failure to avoid reconstruction. Alligator cracking is often associated with failure or the layers below the asphalt and is frequently associated with inadequate road drainage.

There are many other methods of visual rating used, by different organisations. However, the basic principle is to assign and assessment of severity of each of the above categories of distress and to analyse the results to decide on the desirability of one or more forms of maintenance treatment.

Fig 5.7. Block cracking

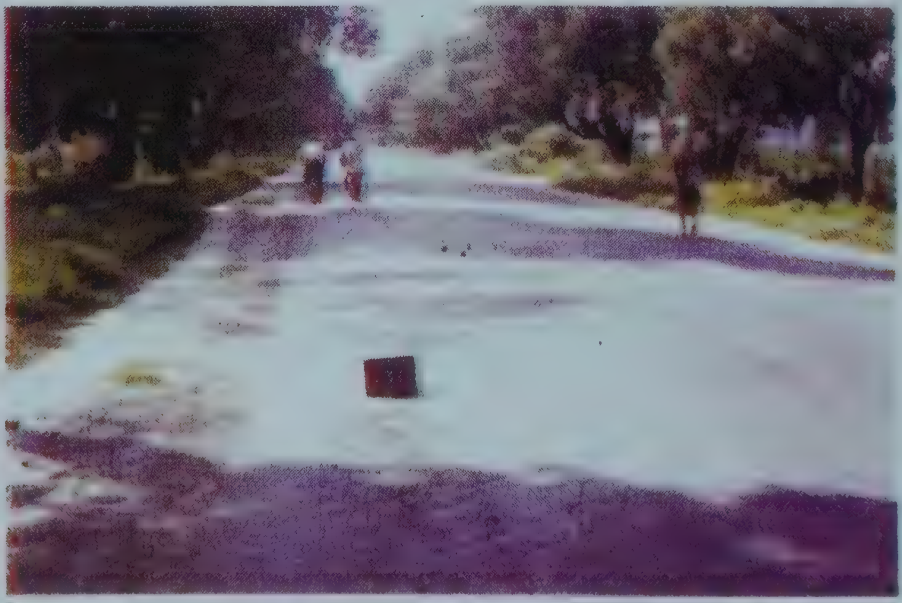


Fig. 5.8. Alligator cracking

Proper assessment of pavement distress and causes diagnosis of its causes is an important step towards the adoption of appropriate correction measures. Pavement distress very often leads to rapid progressive deterioration of the pavement. The bouncing and sway of the vehicles due to ruts, depressions, etc. cause damage to vehicles, and lead to added fuel consumption. They also increase fatigue to the drivers which is an important factor for occurrence of accidents.

5.2.2.2. Riding quality : A newly constructed road gives a smooth ride. As the pavements is subjected to traffic, damage occurs which is reflected in deformation of the pavement and, consequently, the riding quality of the road deteriorates. Therefore, the quality of the ride, as measured by road roughness, is a measure of the road's deterioration with time. Riding quality also affects vehicle-operating costs. The levels of roughness which are taken to indicate the need for maintenance interventions vary a great deal and are particularly influenced by the form of construction.

The riding quality may conveniently be measured by a towed "bump integrator" (Figs. 5.9 and 5.10). A similar device can be attached to the rear axle of a suitable vehicle. In order to give reliable results, however, this type of equipment must be carefully calibrated and must be operated at as uniform a speed as possible.

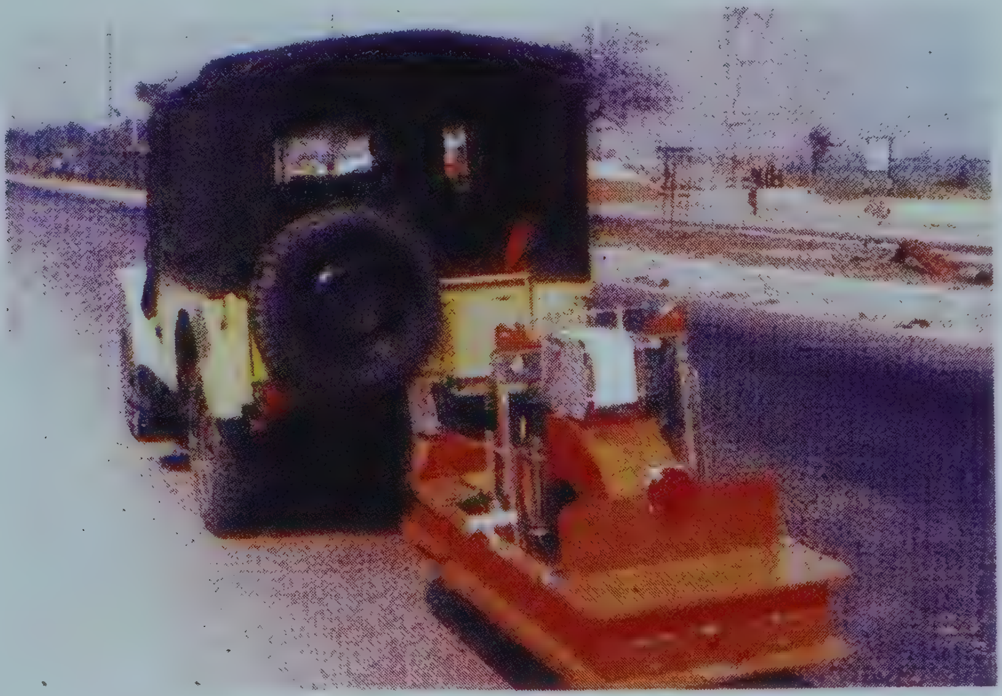


Fig. 5.9. A Bump Integrator Towed by a jeep

For calibration instruments, such as, Dipstick or MERLIN or simple rod and level are generally employed. profilographs and laser-based high technology equipment are also used internationally.

The bump integrator measures the roughness in terms of mm/km. Economic Analysis models, like, HDM (Highway Design Model) of the World Bank use another index known as the IRI (International Roughness Index). Standard equations are available for converting the bump integrator values to IRI.

The roughness values recommended by the Ministry of Road Transport and Highways for various types of surfaces are given in Table 9.1 subsequently.

A good road may gave a roughness of perhaps as little as 1,500 mm/km. whereas, it can be as high as 10,000 mm/km on a very bad road, even more although at roughnesses over about 10,000 mm/km it is usually impractical to maintain the uniform speed necessary for accurate measurement.

5.2.2.3. Skid resistance measurements: Bituminous pavements tend to become smooth as traffic polishes

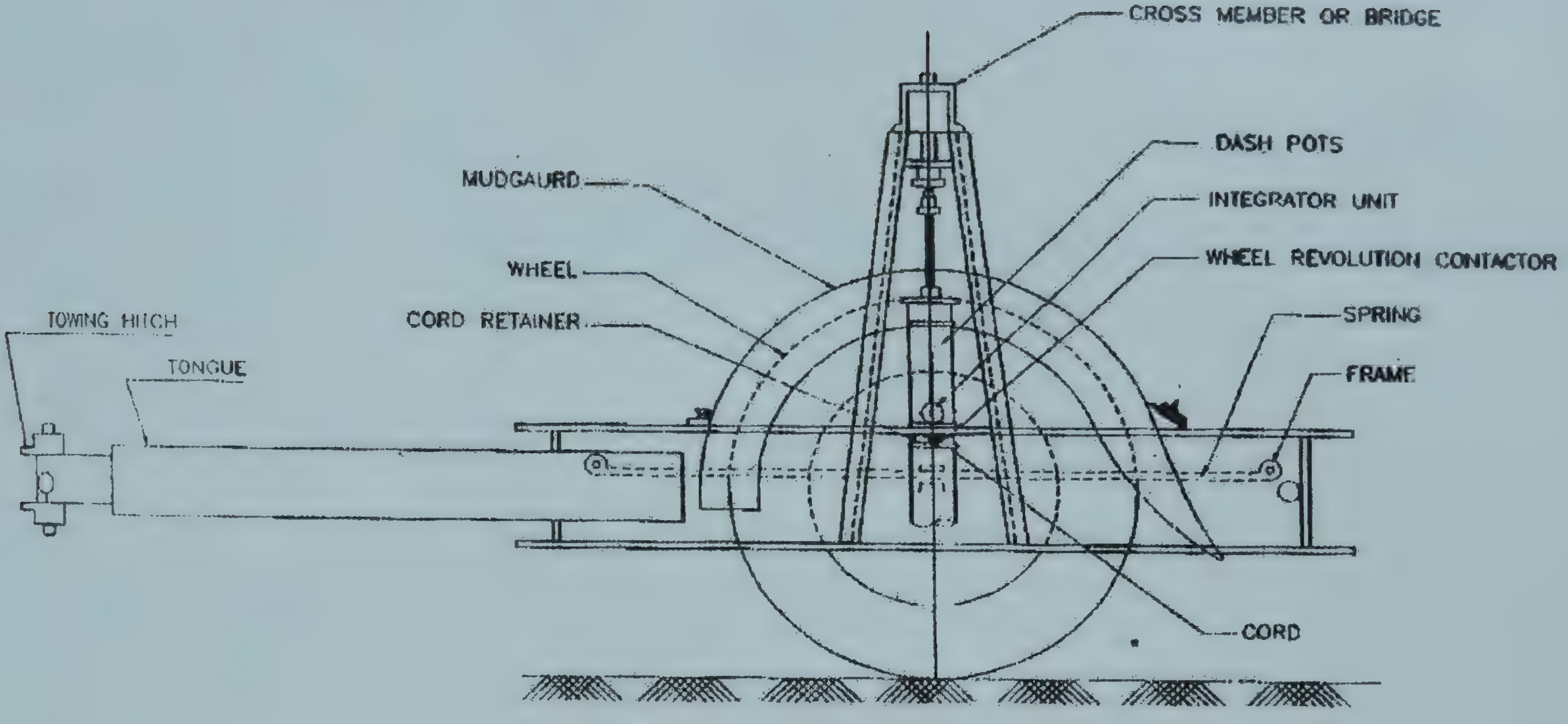


Fig. 5.10. Diagrammatic Sketch of the Bump Integrator

the stone aggregates. very smooth surfaces are skid-prone when wet. Therefore, it is important to periodically measure the skid resistance of roads to be forewarned of the need to intervene and to make the surfaces skid-resistant.

Skid resistance is measured by the co-efficient of friction between the tyre and the road interface. A number of standard test procedures are available. The measurement of the sideways force coefficient by equipment known as SCRIM (Sideway Force co-efficient Routine Investigation Machine) consists of a standard four- wheeled vehicle carrying a fifth wheel set at an angle of 20 degrees to the direction of travel and can be lifted clear of the road when not in use A water tank is carried by the chassis. Speeds in the range of 15 to 100 km/hour can be adopted. A Common speed of measurement is 50 km/hour. The machine measures the sideways friction co-efficient (SFC), which is expressed as follows:-

$$\text{SFC} = \frac{\text{Sideways Force (at right angles to the plane of inclined wheel)}}{\text{Vertical reaction between tyre and road surface}}$$

About 50 to 70 km of road section can be tested in a day.

The method most readily available to a highway engineer is the British portable Tester method. The standard method adopted for testing the Polishing characteristics is to embed the aggregates in a curved mould in cement -sand mortar and subject the sample to accelerated polishing caused by a rotating pneumatic wheel. The specimens are mounted on a circular frame 400 mm dia. The size of each specimen is 45 mm wide x 90.5 mm long. The rubber wheel is 20 mm dia and 5 cm broad, loaded with 40 kg load at a tyre pressure of 3.15 ± 0.15 kg/cm^2. Sand and water are fed to the machine when it is rotated at an r.p.m. of 320 to 325 for 3 hours 15 minutes. The specimens are, thereafter, tested for their polishing value on a British Portable Tester. This machine consists of a rubber sliding shoe which is mounted at the end of a pendulum. The slider, when released, brushes past the specimen and conmes to a halt. The specimen directly measures the Polished Stone value (PSV) on a graduated scale.

5.2.2.4. Ministry's requirements of skid resistance : The Ministry of Road Transport and Highways gives

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[1] Report of the Committee on Norms of Maintenance of Roads in India, M/o RT&H, October 2000.

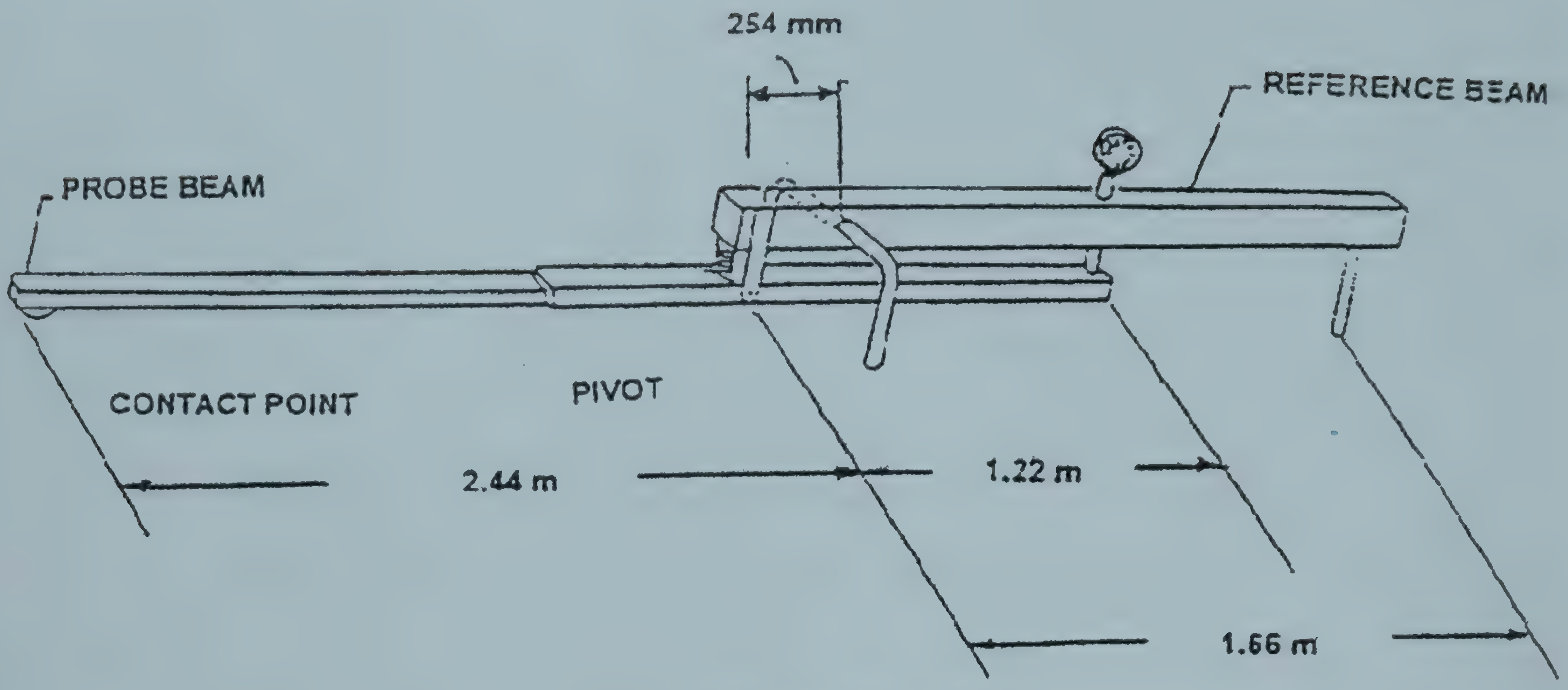

254 mm
REFERENCE BEAM
PROBE BEAM
CONTACT POINT
PIVOT
2.44 m
1.22 m
1.66 m

Fig. 5.11. Benkelman Beam

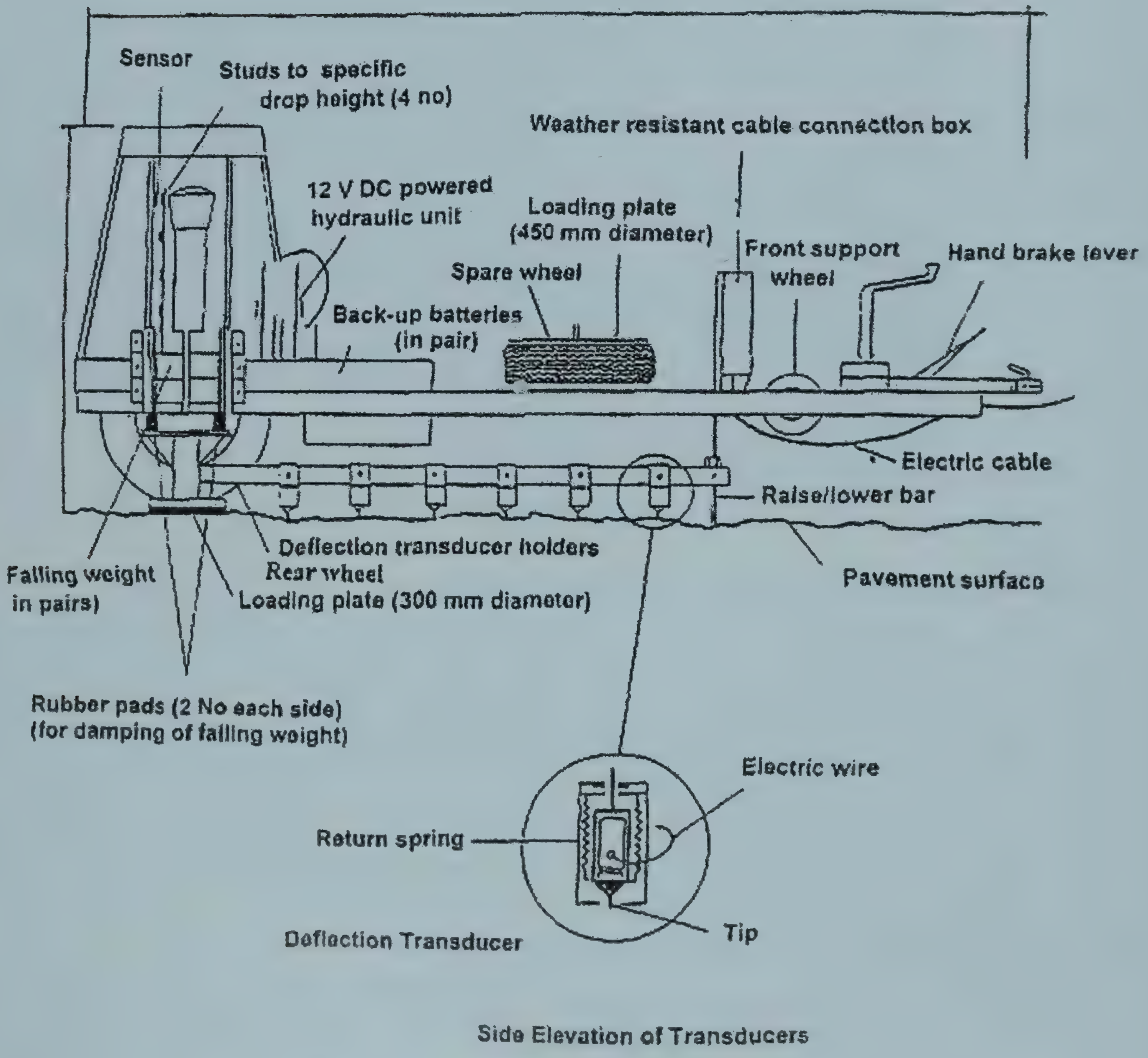

Sensor
Studs to specific drop height (4 no)
Weather resistant cable connection box
12 V DC powered hydraulic unit
Loading plate (450 mm diameter)
Spare wheel
Front support wheel
Hand brake lever
Back-up batteries (in pair)
Electric cable
Raise/lower bar
Deflection transducer holders
Rear wheel
Pavement surface
Falling weight in pairs)
Loading plate (300 mm diameter)
Rubber pads (2 No each side) (for damping of falling weight)
Electric wire
Return spring
Tip
Deflection Transducer
Side Elevation of Transducers

Fig. 5.12. Falling Weight Deflectometer

the minimum desirable requirements' of skid resistance in terms of a Skid number (SN) as per ASTM 274. For three levels of maintenance, the minimum desirable values of Skid Number (SN) are given below :

	Maintenance Level	**Minimum Desirable skid Number (SN)**
Level 1.	Which provides for highest level of comfort, convenience and safety	50
Level 2.	to which the road deteriorates from Level 1 after two to three years of use before fresh maintenance is implemented.	40
Level 3.	the minimum level necessary to protect the investment and provide reasonable levels of safety	35

5.2.2.5. Structural evaluation : Some indication of the structural condition of a pavement may conveniently be gained by measuring the deflection of the road surface under transient loading. The Benkelman Beam (Fig.5.11) method is conveniently simple, while the Lacroix Deflectograph and Falling Weight Deflectometer (Fig. 5.12) are more sophisticated pieces of equipment which, with careful interpretation of data, can give better information. Using Benkelman Beam deflection technique, the Indian Roads Congress provides guidelines (IRC:81) for strengthening of flexible pavements.

5.2.2.6. Existing pavement crust and subgrade characteristics : For assessig rehabilitation requirements for existing pavements, it is necessary to determine the existing pavement crust thickness and composition, subgrade characteristics and strength. Test pits are dug, about 0.6 m x 1.0 m in surface area and taken right to the depth of subgrade. These test pits are preferabley located under the wheel path. The thickness of each layer constituting the pavement crust is noted and representative samples collected. A number of field/laboratory tests are conducted, depending on specific requirements of a road project, more common among them being:

(a) in-situ density and moisture content (IS:2720, part 28)
(b) Field CBR (IS: 2720 Part 31)
(c) Soil characteristics (grain size distribution and Atterberg limits) IS:2720, Parts 4 & 5)
(d) Laboratory moisture - density relationship (IS: 2720, Part 8)
(e) Laboratory CBR (IS:2720, Part 16)
(f) Bitumen content and grading of aggregates in the mix (AASHTO T164)

5.3. Modern Topographical Surveys and Level Control

5.3.1. Need for topographical survey: An accurate topographical survey facilitates the design and estimation of quantities of work. modern survey instruments like total stations and precision levels are a necessary adjunct to the task. Electronic data collection, which can be directly down-loaded to computer, without the need for manual transcription of data can be of considerable assistance in improving the speed of data delivery and, particularly, in reducing errors.

5.3.2. Referencing and level data : Prior to the conduct of any survey work it is essential to establish a comprehensive network of survey beacons and level reference points. It is equally important that these points should all be surveyed into the required grid system and level datum, and that the co-ordinates and levels are carefully checked to ensure against closing errors before any detailed survey commences. It is vital that survey reference and level datum stations are robustly constructed using cast-in-situ concrete pillars, and are located where they are unlikely to be disturbed.

5.3.3. Survey data collection

5.3.3.1. Quantity of survey required: the amount of data to be collected will depend to a great extent on the use to which the data is to be put. In the cale of new construction in areas of flat or gently sloping terrain, intervals between data collection points (usually cross-sections) of 50 metres may be acceptable. On the other hand, where an overlay is to be designed over an uneven existing road surface, a data collection interval of 2 metres may be necessary to achieve an economic design. Much will depend on the judgment of the designer.

5.3.3.2. Current methods: modern road design software often obviates the need to collect ground data at fixed cross-section intervals, concentrating instead on collection of data at key points, such as tops and bottoms of embankments, significant changes in slope and specific features (Typically edges of surfacing, shoulders etc.)

5.3.3.3 Cross sections: Where fixed cross- sectional intervals are required, the following Table 5.1 may act as a guide to the frequency of data necessary.

Table 5.1. Guidance on Intervals Necessary for the Collection of Survey Data for Road Design purposes

	Circumstances	Cross-section interval	Density of Data*
(a)	Design of new roadwork s in flat or gently sloping terrain	50 metres	Ground levels at the proposed road centre-line and at 5 metre intervals each side of centre-line upto 10 metres outside the expected width of the work
(b)	Design of new roadworks in steep or severe terrain	10 to 20 metres	Ground levels at the proposed road centre-line and at 2 to 5 metre intervals each side of centre-line upto 10 metres outside the expected width of the work
(c)	Design of road widening	10 to 20 metres	As (b) above, plus accurate details of the location and levels of the carriageway edges and the estimated location of the existing road centre-line and levels
(d)	Design of road construction in which the levels of the new road surface will not maintain a close correlation with levels of the existing road	10 to 20 metres	As (c) above
(e)	Design of pavement overlay in which the levels of the new construction will bear a close correlation with those of the existing surface	2 to 5 metres	As (c) above, with data at maximum 2 mertre intervals

*In Addition, details of all details of all drainage channels, including tops of banks and stream invert levels, and all other significant features, such as structures and any major changes in ground slope, must be detailed.

5.4 Identification of Naturally Occurring Materials

The construction, maintenance and rehabilitation of road pavements consume a considerable quantity of aggregates, particularly crushed stone aggregates and natural sand. It is an essential element of the proper preparation for a project to determine the nearest and/or most economical sources from which materials of the quality required to construct the works are available. Clearly the distances that it is necessary to haul bulk supplies of materials will have a very significant effect on the overall cost of construction.

The advance investigation into sources of material for use in construction must establish:-

(a) that materials of the required Standard are available;
(b) that the available materials are sufficiently consistent in their properties to comply with the specifications; and
(c) That adequate quantities of materials are available.

CHAPTER 6

ROAD BUILDING PLANT AND EQUIPMENT

6.1. Crushing and Screening Equipment

6.1.1. Aggregates: Aggregates form and important ingredient of bituminous pavement layers. In Chapter 3, the sampling and testing requirements for aggregates has been dealt with. The required properties for aggregates are given in section 500 of the Ministry's Specifications. the aggregates are obtained from crushing of rook, or as naturally occurring sand and gravel or as artificially produced materials, such as, blast furnace slag. General information on rock types and suitability is also given in Chapter 3.

The plant and equipment needed for the production of aggregates from natural rocks is briefly described below.

6.1.2. Requirements of crushing plant : Flat, flaky or elongated aggregate particles are generally not suitable for use in bituminous construction. The crushing plant should be capable of producing particles which are equi-dimensional or cubical in shape" conforming to the grading requirement. Since Each bituminous Material has its own aggregate grading requirements, the plant should be sufficiently flexible to permit production of a good range of aggregate sizes. The capacity of the plant should be more than sufficient to match the capacity of the mixing and laying plants being used.

6.1.3. Types of crushers : Important types of crushers are:

- Jaw crushers
- Gyratory crushers
- Impact crushers
- Rolls crushers

Salient features of the above types of crushers, are given in para 3.2.2. and shown in Figs. 3.1.to 3.6.

One of the commonest mistakes that is made in selecting and running crushing equipments is to attempt to achieve too great a reduction in the average particle size between input and output in a single crushing operation. As a useful general rule, if the ration of the average size of the rock input to a crushing operation to the average size of output from the same piece of equipment is greater than four, then the shape of the product is likely to suffer.

Other factors, which have an important influence on the selection of crushing equipment, are:

- Jaw and gyratory crushers are generally more suitable for the first (primary) stage of crushing, while cone and impact crushers are usually considered more suited to the later stages (secondary and tertiary), when the aggregates to be processed are of smaller size.
- Cone and, particularly, impact crushers are considered to give better shape to the final product, although the type of rock being crushed may also be a significant factor.

The rolls crushers were in use earlier, before the development of cone crushers. The main disadvantages of a roll crusher are its low capacity and wear of roll surface when crushing abrasive rock. Therefore, cone crushers are now being preferred over rolls crushers.

Crushing is, therefore, typically carried out in more than one stage, often using different types of crusher at each stage. A typical three-stage crusher configuration might involve a jaw primary crusher, a cone secondary crusher and an impact tertiary crusher.

Typical nominal capacities of modern crushing equipment may range from 100 to 600 tonnes per hour. The rated outputs are, however, ideal, ideal, and are rarely achieved in practice.

With the increase in emphasis, in more recent times, on environmental controls, it is important that the generation of dust, especially by crushing plant, should be controlled and minimised. Such controls are available with all good modern crushing equipment

6.1.4. Screening : Screening is used for grading material in different sizes. Following are the two main types of screens.

1. **Rotary Screens**

   A rotary screen system consists of a cylinder made out of screening media that rotates around an axis slightly inclined to the horizontal (Fig. 6.1.) The aggregate is fed into the cylinder at the upper elevation of the cylinder. As the cylinder rotates, the 'undersize' is discharged through the walls of the cylinder while the ' oversize' discharges at the lower end. Among the advantages are the ease of multiple sizing by a single unit rotation, simplicity and low cost structure due to the absence of any vibrations. However, the disadvantages are its relatively low capacity and difficulty of maintenance of screening surface.

   In many of the modern installations, the rotary screens are being replaced by the combination of a rotary washing barrel (scrubber) and inclined vibrating screens. However, rotary screens are still in use for low capacity, mobile units.

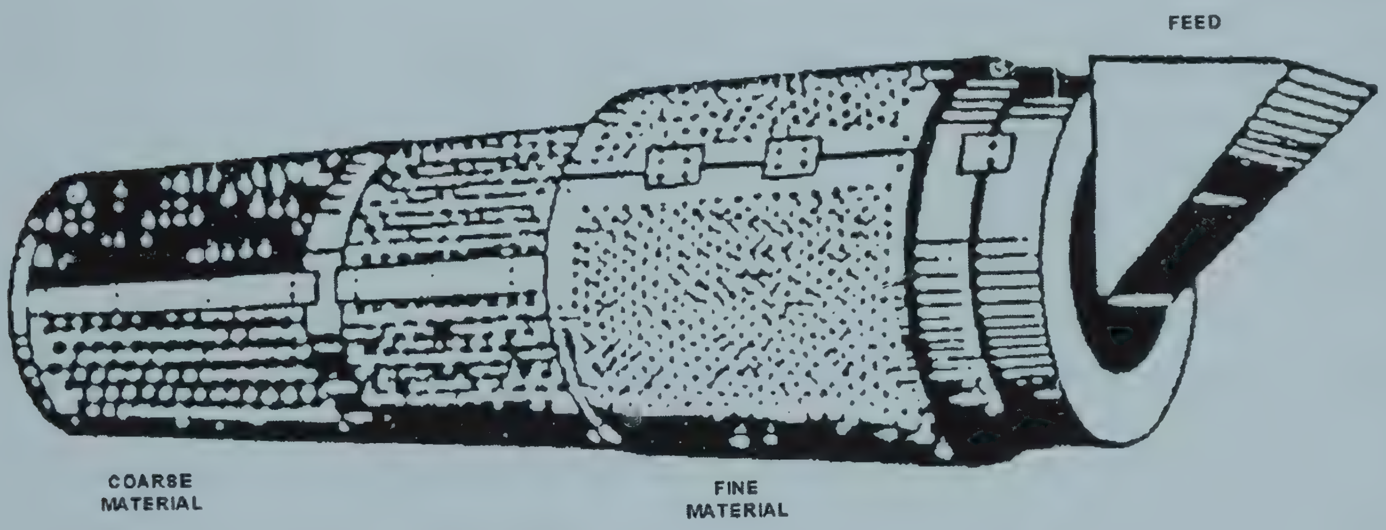
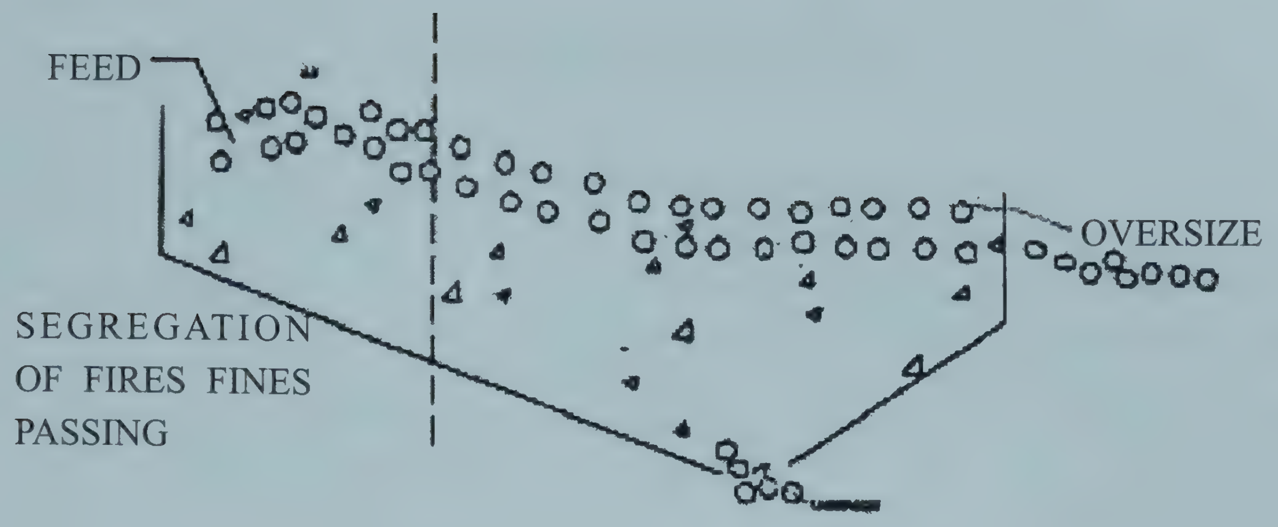


Fig. 6.1. Typical Rotary Screen

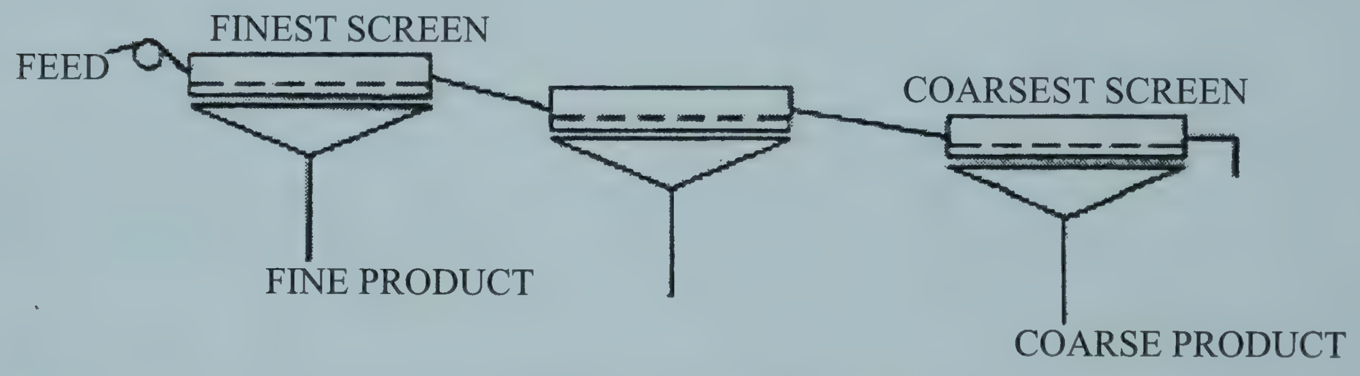
2. **Vibrating Screens**

   The vibrating screens are mounted inclined or horizontal over a frame and are designed to withstand the stresses imposed by vibration. the inclined vibrating screens are perhaps the most common type in the aggregate industry A combination of inclined surface (15° to 20°) and vibration gives rise to continuous screening process during which fines are segregated and pass through the screen, the mechanism of screening by a vibrating screen and sizing by selection/ rejection are shown in Fig. 6.2.

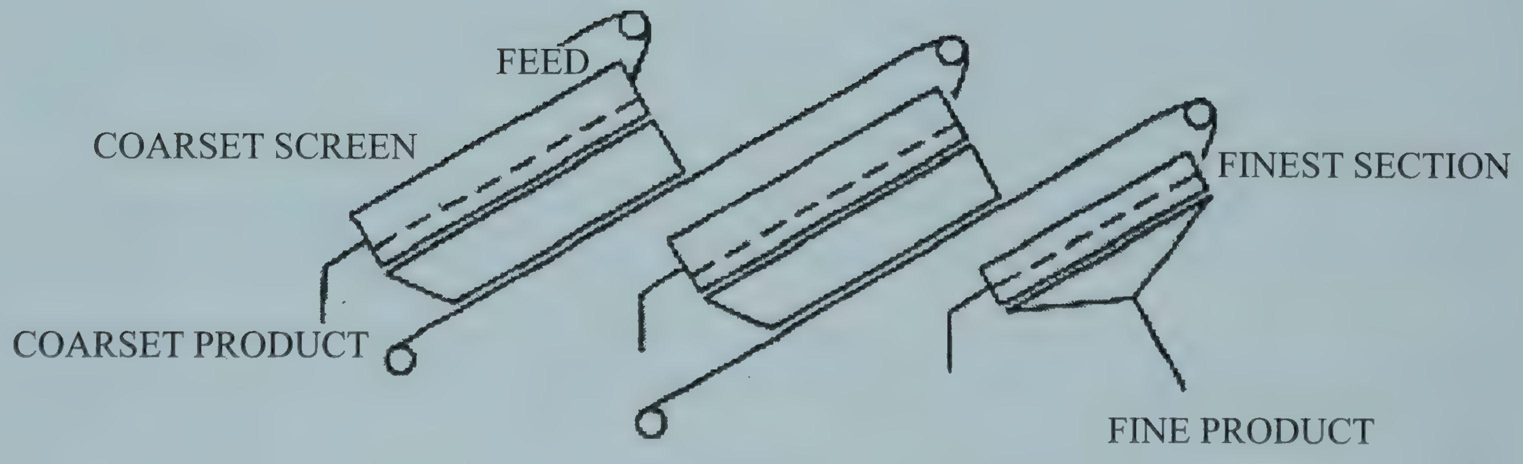
   Basically, the vibrating screens comprise of a vibrating frame, fitted with screening surface. Among the advantages are that the frame may be fitted with single, double, triple or four decks making possible, the simultaneous production of several particle size; high unit capacity; simplicity and low cost. Among the disadvantages are that the screen frame and supporting structure have to be designed to withstand high vibrational loads; greater headroom requirement and taller structure than horizontal screening equipment; dust and noise pollution. Where the screens are horizontal, the advantages are saving in headroom and reduced hight of required structures, but the mechanisms have to be more massive, since the segregation is only due to vibration and there is no advantage available from inclination. inclined vibrating screens are more popular than the horizontal vibrating screens.


FEED
OVERSIZE
SEGREGATION
OF FIRES FINES
PASSING

MECHANISM OF SEREENING


FINEST SCREEN
FEED
COARSEST SCREEN
FINE PRODUCT
COARSE PRODUCT

SIZING BY SELECTION


FEED
COARSET SCREEN
FINEST SECTION
COARSET PRODUCT
FINE PRODUCT

SIZING BY REJECTION

Fig. 6.2. Vibrating Screens: Mechanism and Sizing by Selection/Rejection

6.2. Supply, Storage and Handling of Bituminous Binder

6.2..1. Supply of bituminous binder: Bitumen is produced in the oil refineries, which are located all over the country.

Bitumen may be delivered in bulk or in drums, although the use of drums should be avoided, where possible, for penetration grade bitumen for the following reasons:

- drums are made of thin steel which are non-reusable;
- one drum holds about 160 kg of bitumen and the work of emptying bitumen from the drum, which must first be heated, is tedious and cumbersome;
- contamination of the bitumen by mud and dust during the decanting operation is common;
- considerable wastage of heating fuel and bitumen often takes place;
- the heating of bitumen in drums is frequently supervised and controlled. This may result in gross overheating of the bitumen, often with severe detrimental effects to its properties.

For large jobs, it is more economical to transport bitumen in bulk, This method has many advantages, such as:-

1. Reduction in the wastage of bitumen
2. Avoidance of contamination by mud and leakage losses inherent in handing bitumen in drums

Cutbacks and emulsions are usually supplied in drums. They can also be manufactured on-site by the addition of the appropriate dilutant (e.g., kerosene) to the heated bitumen, although the process is not recommended without the benefit of careful controls. the manufacture of rapid - curing cutback bitumen should not be undertaken on-site at all, owing to the extreme fire risk.

Emulsions in drums have a storage life of a few months dependent on the grade of emulsion, provided the drums are stored under drums are stored under optimum conditions, in accordance with the manufacturer's recommendations. Emulsions can be prepared at the site using an emulsifying plant. For larger projects this may be an economical alternative to purchasing emulsion in drums.

The supply of bulk bitumen from the refineries to the site is done in specially heated tankers carried on rail or in truck-mounted bitumen tankers which gave heating arrangement. The lorries are available with tanks of 5,000 - 15000 litre capacity. A diagrammatic sketch of a bulk bitumen tanker carried by road is given in Fig. 6.3.

6.2.2. Storage of bituminous binder: Bitumen is stored in tanks at the site of the hot - mix plant. The storage capacity should be sufficient to maintain uniform and uninterrupted operations making due allowance for delays in the arrival of further consignments.

The storage tanks should be calibrated so that the amount of material available at any time in a tank can be easily determined. Low and high level alarms should be installed, Tanks should have a thermometer to record the temperature.

The heating is done by the circulation of steam or by gas firing or hot oil through coils in the tank, or it may be done electrically.

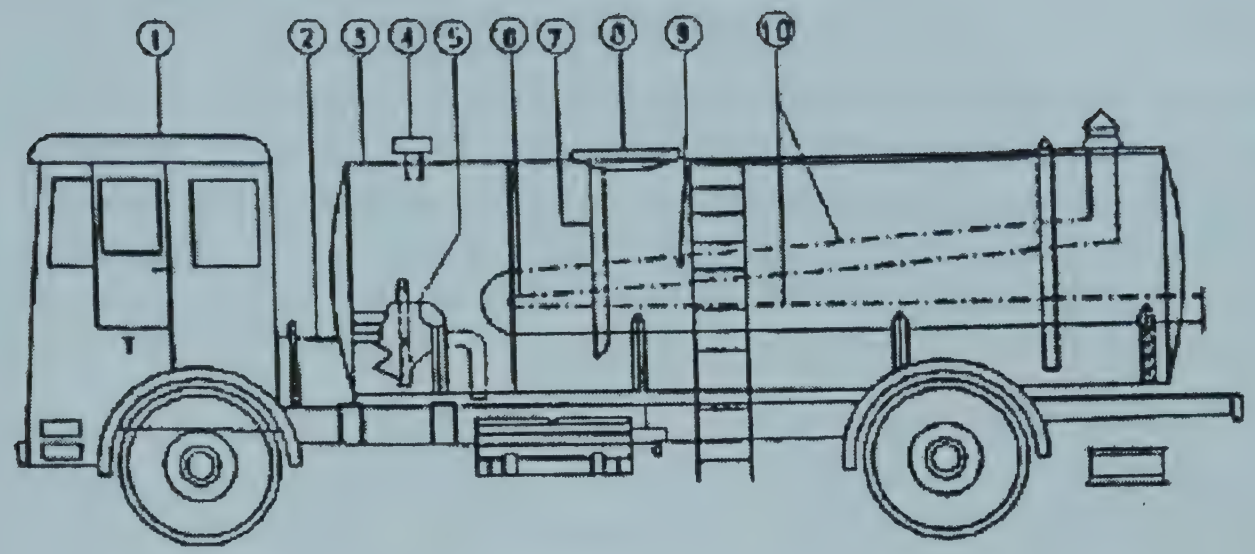
All storage tanks, pumps, transfer lines and weigh buckets should have heating coils or jackets to maintain the required temperature; the latest tanks have thermostatic control.

Vertical storage tanks are preferable to horizontal tanks to minimise the free surface-to-volume ratio and thus the risk of oxidation.

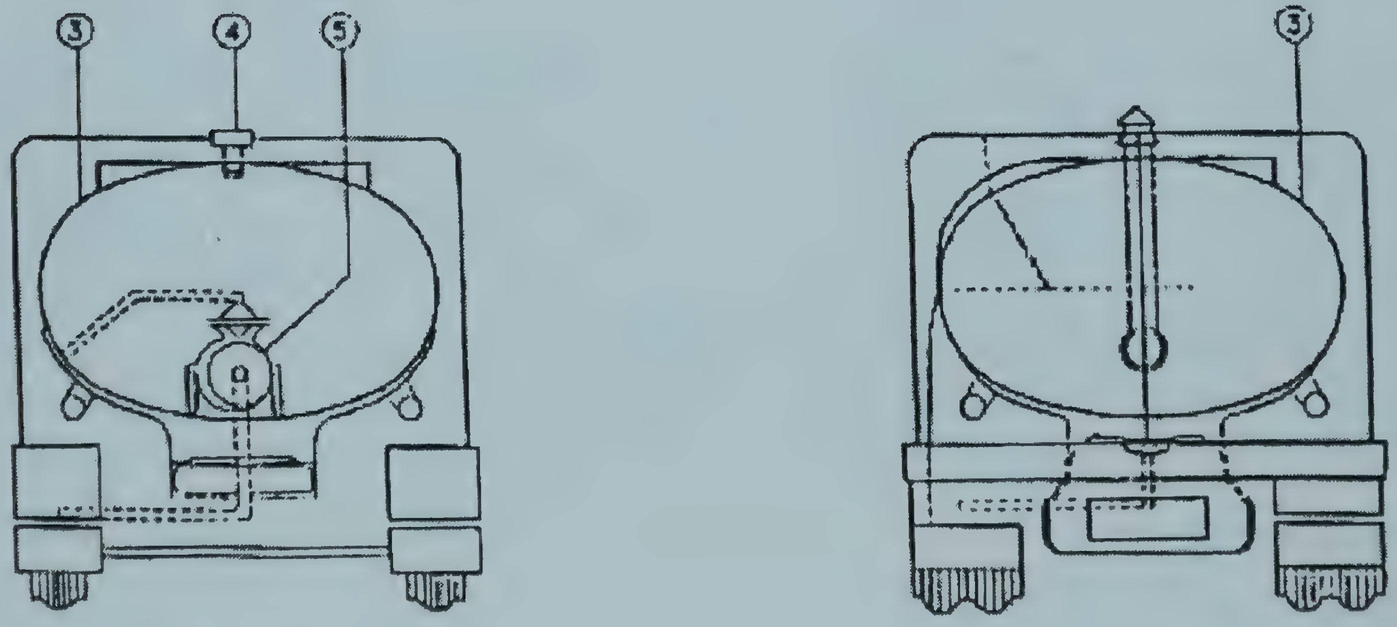
The return lines in a recirculation system should re-enter the storage tank below the bitumen surface to prevent hot bitumen cascading through the air.

The tanks should be labelled to indicate the grade of bitumen. When the grade is changed, it is important that the label is also changed.

If the bitumen must be stored for a long time, say more than one week, without the addition of fresh bitumen, the



ELEVATION



CROSS-SECTION

END VIEW

1. engine
2. power Tank of shaft
3. Tank
4. pressure vent
5. pump
6. Diesel Tank
7. Tank Content Gauge
8. Manhole Cover
9. Thermometer
10. flue pipe

Fig. 6.3. Bitumen Tanker

temperature should be reduced to around 20° C or 25° C above the softening point, and where possible, recirculation should be stopped.

During storage of bituminous emulsion, a skin of bitumen can form on the surface of the emulsion when exposed to air. It is, therefore, necessary that tall, vertical tanks be used that expose the least amount of surface area to the air. Horizontal tanks can be used only for short-term field storage, the tendency towards "skinning" being reduced by keeping horizontal tanks full to minimise the area exposed to air. Side-entering propellers, located about

1 m from the tank bottom, may be used to agitate the emulsion and prevent surface skin formation. Large -diameter slow-turning propellers are the best but overmixing should be avoided.

6.2.3. Handing of bituminous materials: Bitumen can be damaged by over-heating, which may result in the loss of the loss of the more volatile fractions and a permanent change in the adhesive characteristics of the bitumen. It should not be heated to working temperatures by the uncontrolled application of fire to the containers in which it was delivered, particularly when this results in significant differential temperatures within the bitumen. It should only be heated to working temperatures with the use of properly designed equipment, including provision for circulation of bitumen and accurate temperature measurement.

Since bitumen is handled at high temperatures, great care is needed to prevent fire hazards and guard the safety of workers. First aid kits for skin burns must be installed at the site. Persons affected by bitumen fumes (which may contain poisonous gases) should be removed from the site immediately to fresh air and medical help promptly given. Protective clothing and rubber boots should be provided for personnel. Fire extinguishers must be available at site at all times.

It is also of particular importance to study and adhere to the safety recommendations of the manufacturer of any equipment involved in the transportation, storage, heating and use of the bitumen.

Bituminous Emulsions that have been in prolonged storage should be gently agitated; this may be done by recirculation or, if in drums, by rolling these back and forth Emulsions should be hauled in trucks with battle plates. When diluting a bituminous emulsion, check the compatibility of the water with the emulsion by testing a small quantity; if possible, use warm water for diluting. Always add the water slowly to the emulsion and not the emulsion to water It is not desirable to mix different classes, types and grades of emulsion and not the emulsion to water. It not desirable to mix different classes, types and grades of emulsified bitumen in storage tanks, tucks and distributors. The Rapid Setting (RS) grades should not be diluted with water. Medium and Slow Setting (MS & SS) grades may be diluted but the water must always be added slowly to the emulsion. An emulsion should never be added to a tank of water when diluting. When heating a bituminous emulsion, agitate it gently to eliminate or reduce skin formation.

6.3. Bitumen Distributors

6.3.1. General: the application of a thin film of binder on a road surface is an integral part of many construction processes. These include:

1. prime coat
2. Tack cot
3. surface dressing
4. Liquid seal coat
5. Fog spray

Modern methods of construction invariably employ a mechanical binder Distributor.

The type of distributor employed depends on the type of the binder used. Normally, penetration grade bitumen, with or without additives, cutbacks and emulsions are used as binder The first is used hot, (above 120°C) . the second, warm. (25°C), and the third cold.

6.3.2. Components of a bitumen distributor: Bitumen Distributors are generally self-propelled units comprising of the following components:-

1. Heated insulate bitumen storage tank, of a capacity 5,000 - 20,000 litres
2. spray bar with nozzles

3. pump for delivering binder to spray bar
4. Hand held spray bar to attend to difficult areas and corners where distributor cannot reach
5. A dial type of thermometer fitted on the body to give the correct temperature of the binder
6. An accurate tachometer copable of measuring travel speeds and a locking device for fixing the desired speed
7. An electronic control device that will control the quantity of bitumen sprayed as well as the parameters of spraying, e g,. number of nozzles, speed of truck, temperature of the fluid, etc.

Fig. 6.4 gives a diagrammatic view of the unit.

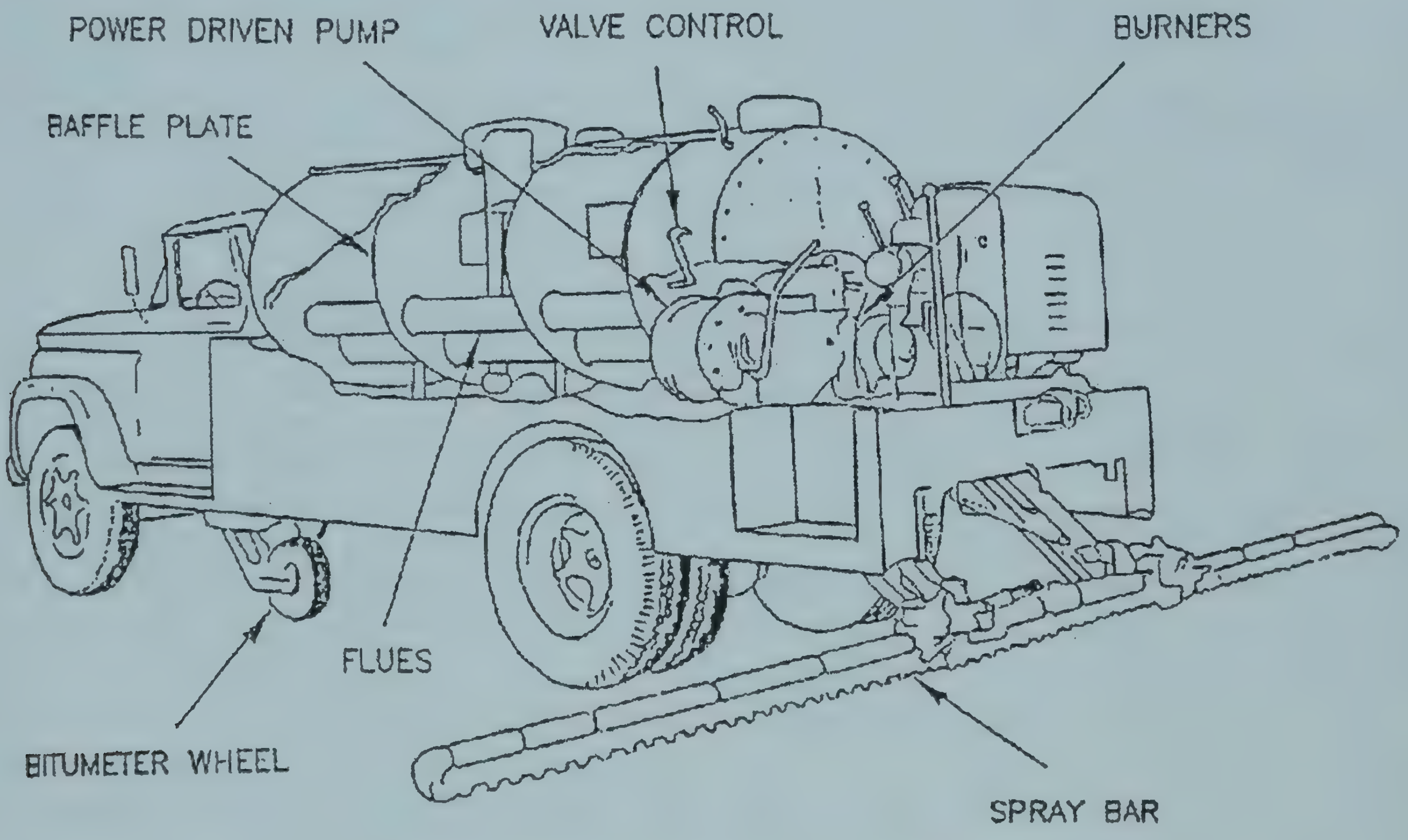


Fig. 6.4. Typical Bitumen Distributor

The system of heating bitumen is generally through a hot oil boiler, installed on board the distributor and thermic fluid oil circulated through a set of coils installed in the tank. The heating system, can, thus, be either through a burner using diesel or kerosene or electronic heater.

The spray bar can be of 3 different categories. while the first one just distributes the binder, the second category is with 'crculation of the binder', i.e., the binder is in a closed circuit between the tank, the spray bar and then returning to the tank, avoiding the possibility of bitumen solidifying in the bar and keeping the spraying bar at the temperature of binder. The third category has circulation of the binder plus a set of coils built in to allow circulation of Hot oil into the spray bar, thus maintaining accurate temperature at all times.

For the application of binder, there are different types of nozzles (or jets) namely slotted jets and atomising or whirling spray jets. The ideal viscosity of bitumen for spraying through these types of jets are distinctly different (check manufacturer's recommendation), and, therefore, the recommended temperatures at which each individual type and grade of bitumen should be sprayed, through each type of jet, will vary.

The spray bars cover widths from 1.8 m to 9.1 m in one pass, depending on their width and pump's capacity. In order to ensure that the spray fans do not interfere with each other, the angle of the long axis of the nozzle openings needs to be adjusted, Fig. 6.5 A. The nozzle angle varies with the make of the Equipment but is usually 15° to 30° The height of the spray bar above the road surface also needs to be adjusted to ensure uniformity of spray and the needed height should be maintained all through the spraying operation. However, it set too high, wind can distort the spray fans. A triple coverage with 100 mm spacing of nozzles is shown in Fig. 6.5B. If the spacing in-between nozzles were 150 mm, the needed height of the spray bar would have been so high above the road surface that wind could possibly distort the spray fans. The nozzles have to be controlled individually. The opening and closing of these nozzles con be manually operated or pneumatically operated. A control system should be installed which makes it possible for the operator to modify at any time, the various parameters of spraying, e.g., either 'start' or 'stop' or 'modify' the number of nozzles opened, etc. Basically, the rate of spread is a function of four parameters viz, viscosity of the binder, speed of the truck, speed of the truck and the number of nozzles in the spray bar. The operator has to ensure that the quality of binder passing through a nozzle is the one specified and that the binder has the desired characteristics, While spraying double or triple coverage, the quantity of bitumen sprayed from lst and 2nd and nozzles of the spray bar will have lesser quantity at the edges of the road compared to other nozzles. Hence, the lst and 2nd and nozzles of the spray bar will have different sizes to have uniform spray of bitumen.

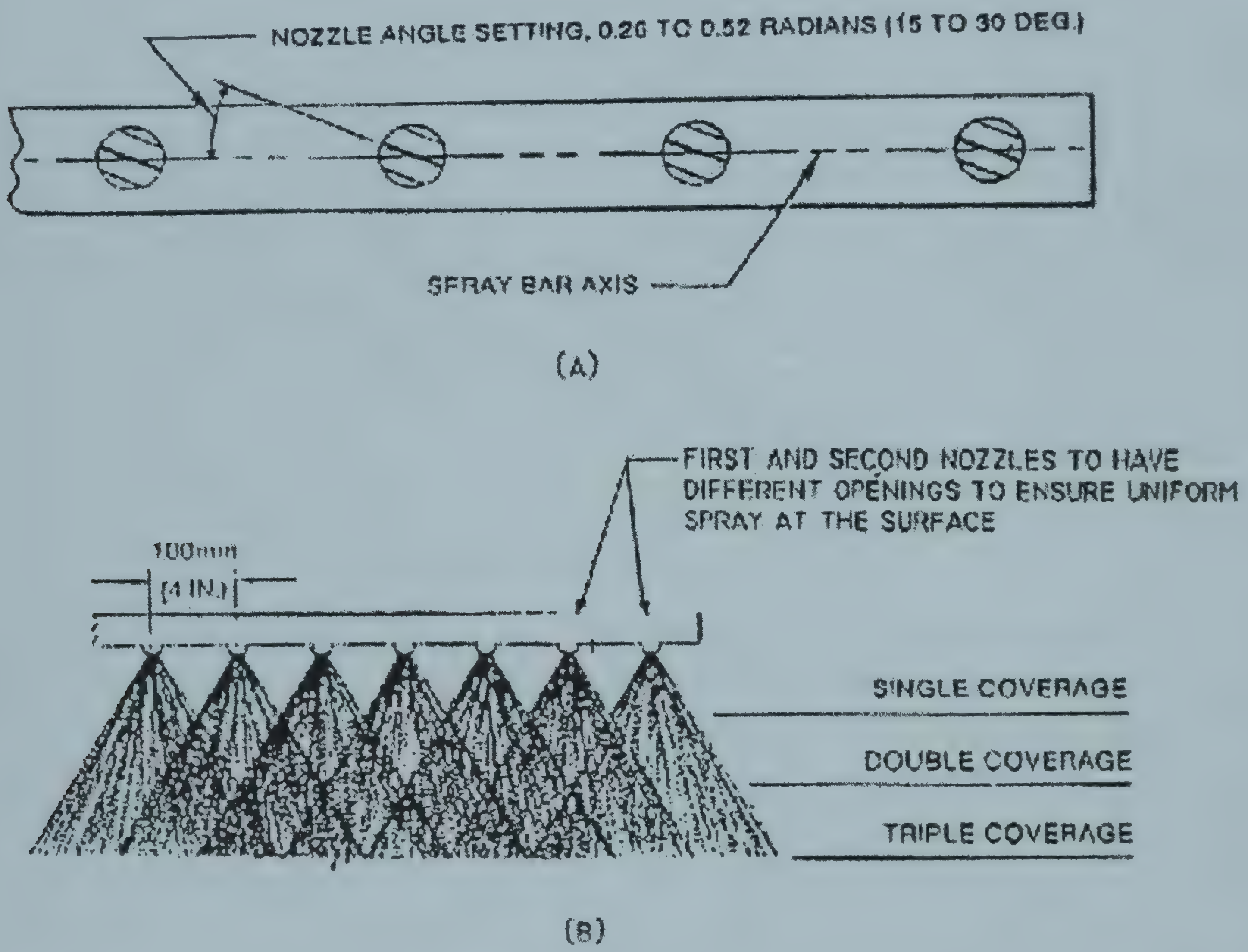

NOZZLE ANGLE SETTING, 0.26 TO 0.52 RADIANS (15 TO 30 DEG.)
SPRAY BAR AXIS
(A)
FIRST AND SECOND NOZZLES TO HAVE DIFFERENT OPENINGS TO ENSURE UNIFORM SPRAY AT THE SURFACE
100mm
(4 IN.)
SINGLE COVERAGE
DOUBLE COVERAGE
TRIPLE COVERAGE
(B)

Fig. 6.5. Adjustments needed in Spray Bar

All distributors should have a bitumen wheel, or tachometer, which can measure the rate of the travel and distance covered. Electronically and laser operated speedometers are common in modern spray tankers. As the distributor is required to move at slow speeds, of the order of 5-10 km/hr, there are usually arrangements to lock the accelerator at the required speed. In modern distributors, the speed of the pump varies with the speed of the truck. thus delivering always the quantity of binder required, irrespective of the speed of the truck.

It is, therefore, of considerable importance, if a good quality of construction is to be achieved, to regularly check and calibrate both the uniformity of rate of spray of bitumen along the entire length of the spray-bar and the accuracy of the tachometer. The frequency with which these checks are carried out will depend to some extent on the regularity with which the equipment is used, but in no case should the interval between checks be greater than six months.

Though, heated bitumen distributors can also be used for emulsions, specially designed emulsion distributors are available.

The following points need to be given adequate attention in using bitumen distributors:

1. The spray bar and nozzles should be cleaned regularly to ensure free flow of jets.
2. The height of the spray bar above the road surface must be correctly adjusted and kept constant throughout the operation.
3. The fate of application depends upon the speed of travel and the operator should have a calibration chart that relates the rate of application to the fate of travel. The distributor con also be equipped with electronic control system ensuring proper rate of application at any given point of time.
4. The uniformity of application should be checked periodically by a tray test.
5. Fire extinguishers should be kept in readiness for emergency use.
6. Suitable arrangements of side flaps for protecting and side-walks from getting sprayed should be installed.
7. The operator and helper operating the bitumen distributors should be experienced personnel.

6.4. Chip spreaders

6.4.1. Genera : Chip spreaders are used for spreading the cover aggregates in surface dressing work. Although, chips spread manually can be satisfactory for small works, if trained personnel are available, it is advisable to use mechanical spreaders for larger jobs, particularly when using a heated binder, where the length of time between applying hot binder to the road and the subsequent application of chips is critical. Overall, mechanical spreaders yield much better results, giving a more even distribution and faster application.

6.4.2. Types of chip spreaders : The three main types of chip spreaders are:

1. Metering or non-metering "tail-board" types;
2. pushed metering types; and
3. self-propelled metering types.

Non- Metering "gritters" of the tail- board type have a tail-board adapter attached to a tipping truck. A serrated steel comb controls the flow of chips. The tipper lorry is driven in reverse as the chips are spread over the binder film so that the truck runs on the chips, not on the binder. The rate of spread is dependent upon the speed of the truck and the gravity effect on the stone in the raised back of the truck. Thus, a good deal of skill is needed on the part of the truck driver to get an even spread.

An improvement over the above is a metering device which consists of a roller over which the chips are delivered, the roller is either driven from the road wheels or a fifth wheel. In this way, variations in the speed of the tipper produce variations in the rate of discharge of the chips.

Pushed metered chip spreaders are hoppers on wheels propelled by the aggregate tippers. The feed is driven by the wheels of the hopper and the chips in the hopper are constantly replenished from the raised body of the tipper. Hoppers contain augers to distribute the aggregate to the full width of the box.

Self- propelled metered chip spreaders are the most effective machines available (Fig. 6.6.) They have a hoper at the rear into which the chips are discharged from the delivering tipper tuck. During transfer of chips, the tipper truck is towed along in reverse by the chip spreader. Conveyor belts transfer the chips to a transverse hopper at the front of the machine. At the bottom of the hoper is the metering roll that delivers the chips to the road pavement.

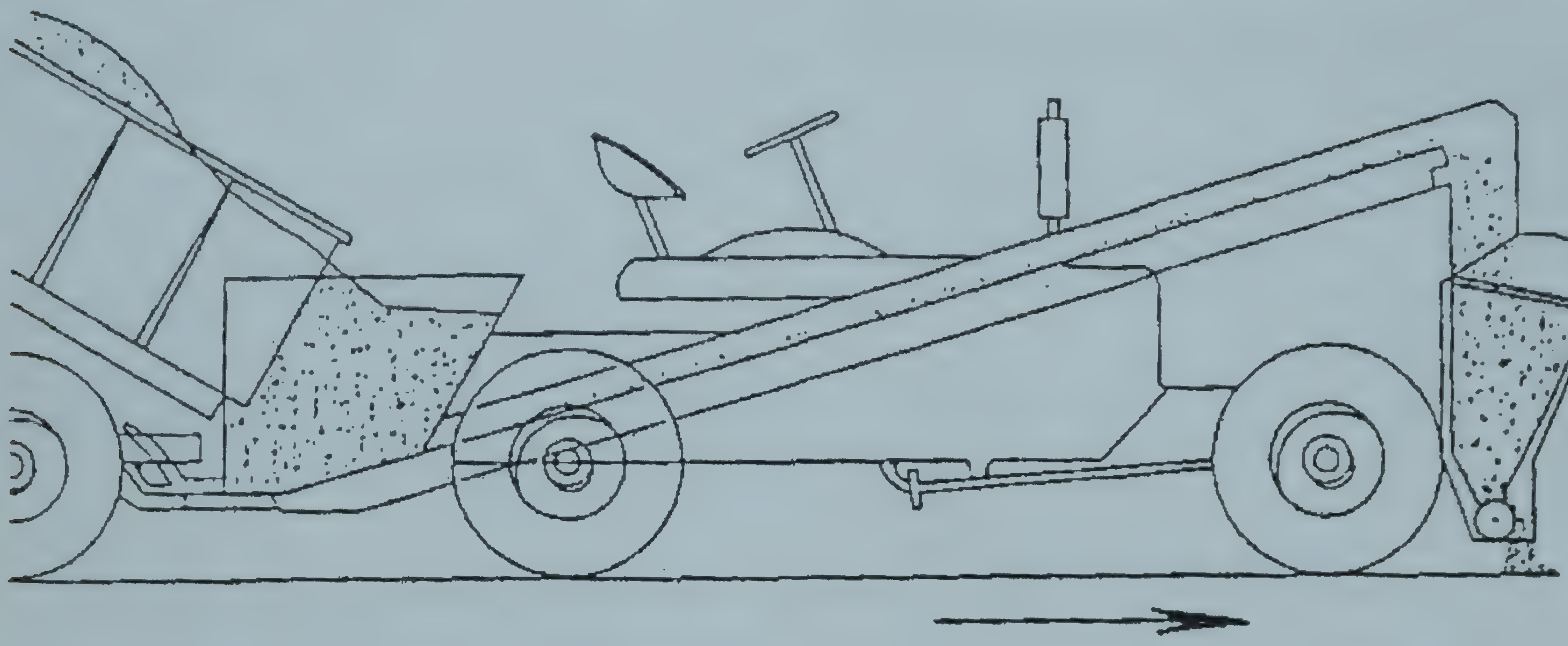


Fig. 6.6. Flow of aggregate through Mechanical spreader

6.4.3. The Operation of chip spreaders: The operation of chip spreaders at a steady speed in an uninterrupted manner is possible only if there is an adequate stock-pile of chips and there are enough tippers to transport them. Depending upon the haulage distance, a minimum of four to five tippers are required.

6.4.4. Combination of bitumen and chip spreaders: Combined bitumen and chip spreaders are available although they are mainly suitable for low volume, independent operations and as such, their main application is for maintenance work (Fig. 6.7).

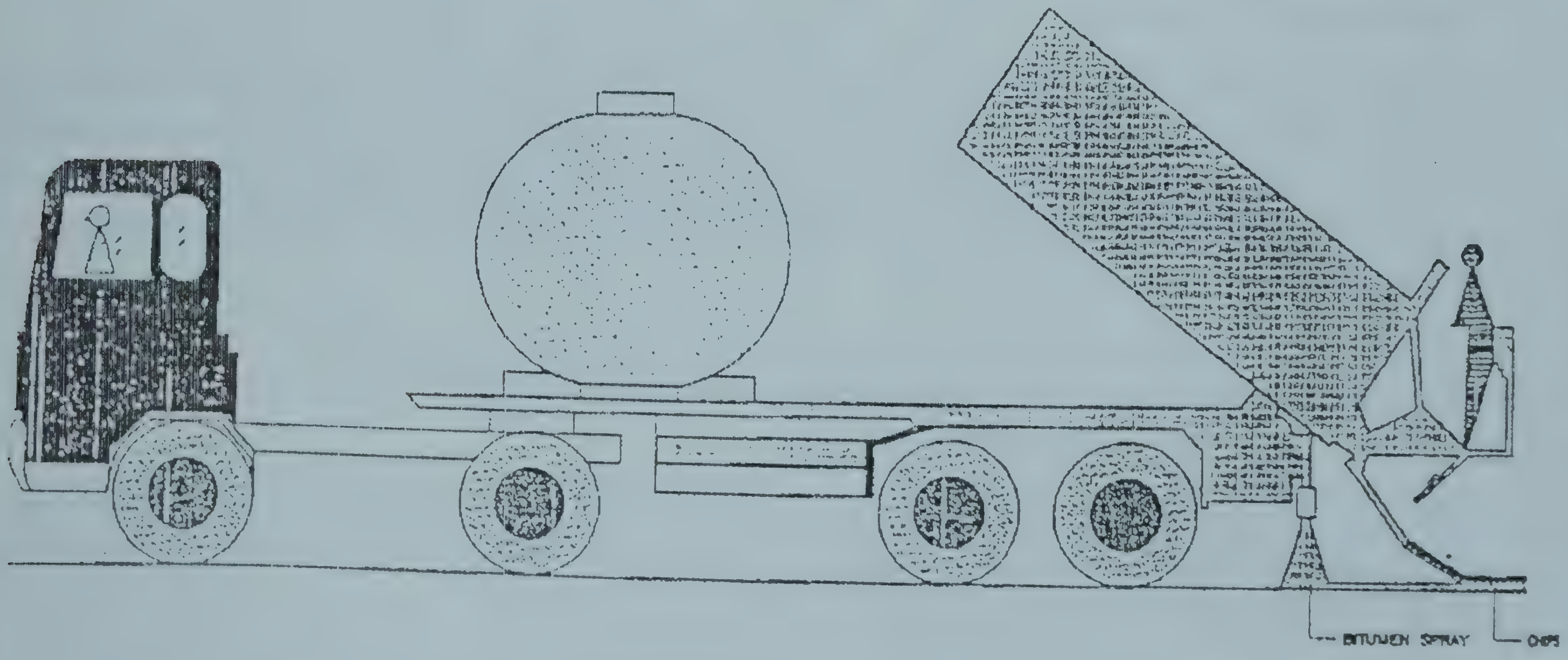


Fig. 6.7. Combined Bitumen Sprayer and Chip Spreader

6.5. Bituminous Hot Mix plants

6.5.1. Plant types : For the production of a hot bituminous paving mixture, aggregates are blended, heated and dried and then mixed thoroughly with hot bitumen. The two types of mixing facilities which are widely used all the world over can broadly be classified as under:

- Batch mixing plant
- Drum mixing plant

Any of the above types can also be broadly classified as: stationary, i.e., permanently situated and not required to be dismantled and moved suited or portable, i.e., copable of being dismantled and moved by road or rail.

6.5.1.1. Batch mixing plant: In a batch mixing plant, various sizes of hot aggregates in storage bins are withdrawn in pre- in pre- determined quantities to make one 'batch' before mixing with a predetermined quantity of bitumen. It comprises the following :

a) Cold Aggregate Storage
b) Conveyor and Cold Elevator
c) Dryer
d) Temperature Measurement Device
e) Dust Collector (Cyclone and Filter)
f) Hot Elvators
g) Hot Screening Unit
h) Hot aggregate Storage Bins
i) Filler Silo
j) Bitumen supply Arrangement
K) Measuring and mixing of aggregate and Bitumen
l) Discharge into truck/hot storage silo

6.5.1.2. Drum mixing plant : In comparison to a batch mixing plant, the drum mixing plant is continous in operation. Here, the cold aggregates are proportioned and heated as well as mixed with a predetermined proportion of hot bitumen in the same drum. It comprises the following :

a) Cold Aggregate Storage
b) Proportioning
c) Conveyor and Cold Elevator
d) Bitumen Supply Arrangement
e) Heating and Mixing of Aggregate and Bitumen
f) Dust Collector
g) Storage Silo

6.5.2. Site selection (see also 8.2.1.1.)

1. For the temporary location of a portable plant and especially for the permanent location of a stationary plant, careful selection of site is of utmost importance.

2. A plan, to scale, of the area available for siting the plant should first be obtained, with cardinal directions shown on it. A rough sketch, again to scale, showing the location of the different units should be made to examine whether a continuous uninterrupted flow pattern, with availability of a short and easy exit for the end product, is feasible or not.

3. It is very important that adequate space is available for storage of a sufficient quantity of each size of aggregate

to be used, as well as the bitumen and filler. The material in adjacent aggregate stockpiles must not intermix. If necessary, dividing walls should be provided. the stockpiles must be positioned for maximum efficiency loading of the aggregate hoppers or cold bins. To avoid contamination of the aggregates is is advisable to locate stockpiles on a suitable hard standing. If trucks bring in aggregates from the crusher/screening plant they must be routed so that they do not interfere with operations at the mixing plant or with the delivery of mixed material from the plant.

4. The access roads to the plant, the direction of the generally prevailing wind, the slope of the ground, and the dirction of flow of surface water should all be taken into account in the proper location of the units. This is to minimise dust or fume nuisance, unsanitary conditions and reducing traffic circulation to a minimum. Fire risks should also be taken into account,
5. If possible, the entire plant site should be isolated from external flows of surface water and consideration for the proper drainage within the site is important in order to prevent contamination of ground water and local surface water resources.
6. For a permanent stationary plant, the location of the weighbridge, laboratory and offices and workshops, etc. should be up - wind of the plant to maximise a pollution free environment for the work people.
7. Proimity to any residential or business areas which may get adversely affected by locating the plant at a particular site should be an important consideration in site selection.

6.5.3. Components of a batch mixing plant : In a Batch Mixing plant (Flow diagram in Fig. 6.8) the aggregates in different sizes are removed in required amounts from storage bins or stockpiles and passed through a dryer where these are dried and heated. The Hot aggregates then pass over a screening unit which separates them into different sized fractions and deposits them in hot storage bins. The aggregates and mineral filler are then withdrawn in required amounts, combined with bitumen and mixed thoroughly. The various components of a batch mixing plant are briefly outlined in the following sub-paras.

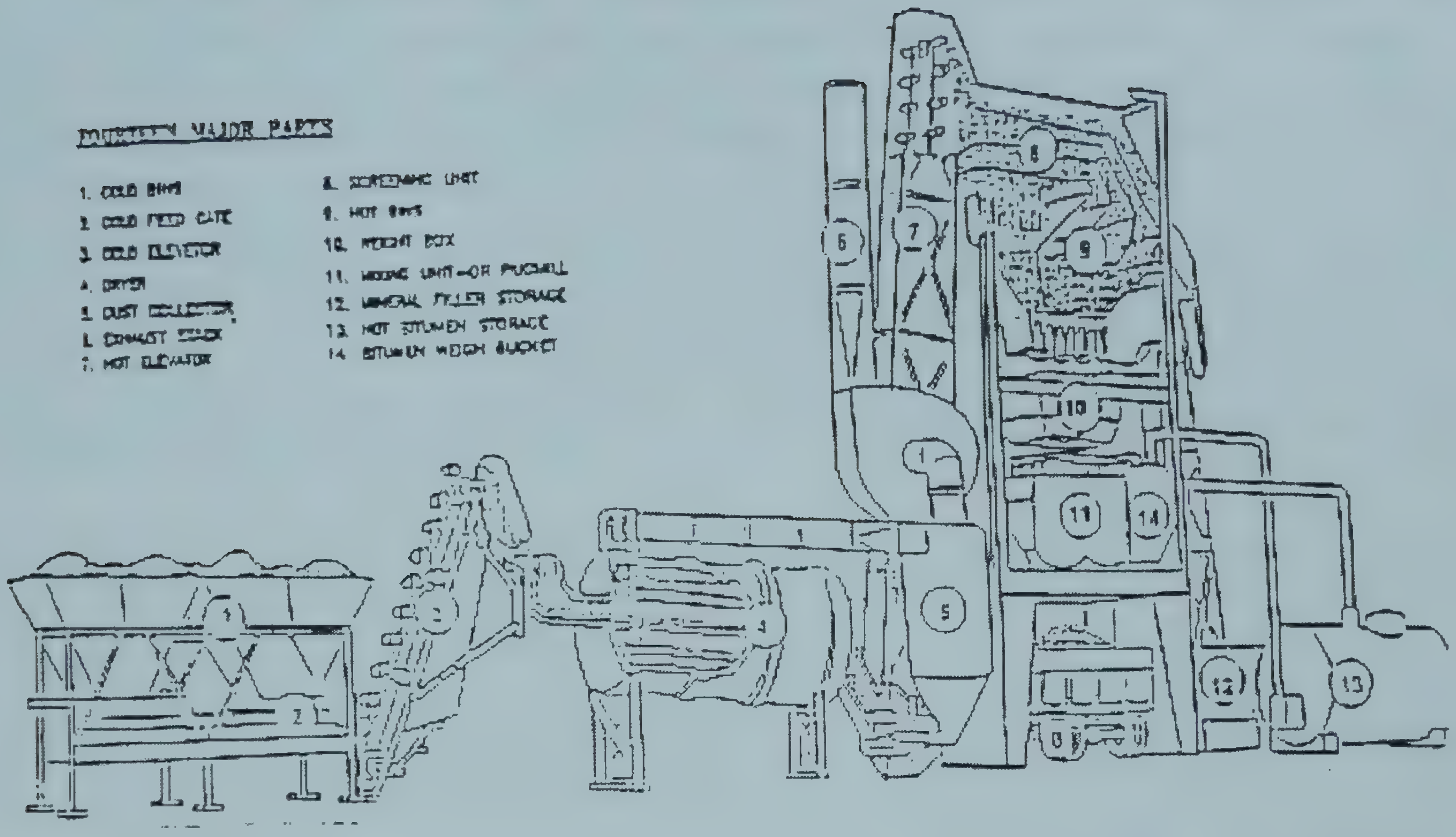
6.5.3.1. Cold aggregate bins : The cold aggregates bins should be at least four in number, fitted with discharge gates which can be adjusted and calibrated to control the flow of aggregates of different sizes in the desired amounts, required by the grading of the mix. In order to have free flow of fines from the bin, it is advisable to have a vibrator fitted on bin to intermittently shake it. The total capacity of the bins should generally be at least three times the dead load capacity of the mixer. It may be pointed out here that since mineral filler is subject to caking or hardening from moisture. It has to be handled differently than other aggregates and separate storage is provided (as shown in Fig. 6.8) where it is protected from moisture.

6.5.3.2. Conveyor and cold elevator: The cold bin aggregate feeding system discharges onto a conveyor in pre-set quantities to give the required grading and then into the cold elevator which discharges into the dryer. Belt conveyors below each bin should have variable speed drive motors. There should be electronic load sensor on the main conveyor for measuring the flow of aggregates.

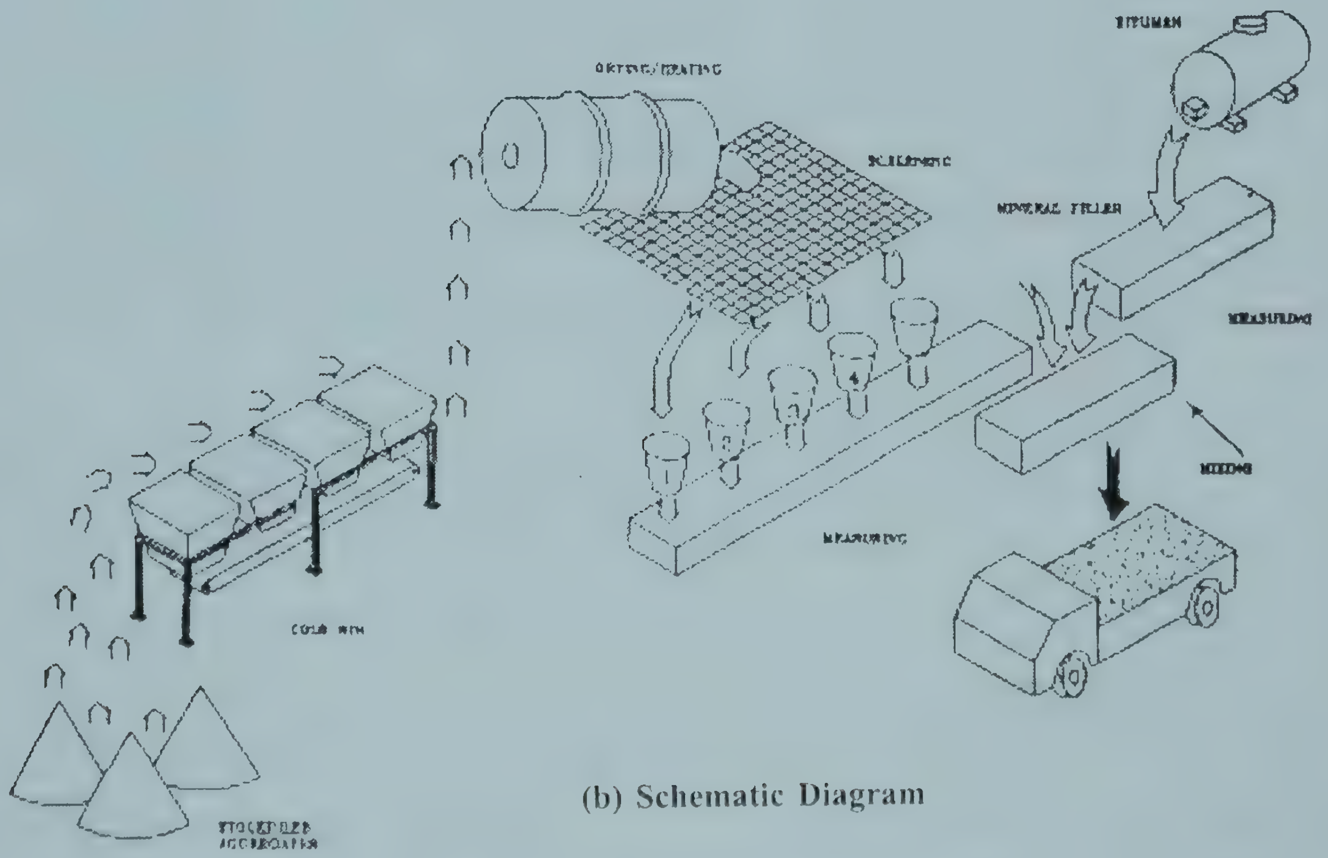
6.5.3.3. Dryer: The main functions of the dryer are: (a) removal of moisture from the aggregate, accomplished by the heat the heat of the dryer which vapourises the moisture and the vapour is drawn off by the draught (b) to heat the aggregates so that they are at the right temperature for mixing with bitumen in the pug mill.

Basically, the dryer comprises a revolving cylinder usually from 1 to 3 m in diameter and from 6 to 12 m in length in which the aggregate is dried and heated by an oil or gas burner. The cylinder is equipped with longitudinal cups or channels, called "Lifting Flights" which lift the aggregate and drop it in veils through the burner flame and hot gases. The time required for the aggregate to pass through the dryer is dependent on its speed, inclination of the cylinder, diameter and the arrangement and number of “flights”.

6.5.3.4. Temperature measurement device : Accurate information of aggregate temperatures after heating is essential for quality control since under - heating of aggregate may prevent full coating and adhesion of binder to the


FOURTEEN MAJOR PARTS
1. COLD BINS
2. COLD FEED GATE
3. COLD ELEVATOR
4. DRYER
5. DUST COLLECTOR
6. EXHAUST STACK
7. HOT ELEVATOR
8. SCREENING UNIT
9. HOT BINS
10. WEIGHT BOX
11. MIXING UNIT—OR PUGMILL
12. MINERAL FILLER STORAGE
13. HOT BITUMEN STORAGE
14. BITUMEN WEIGH BUCKET
1
2
3
4
5
6
7
8
9
10
11
12
13
14

(a) Cutback View


BITUMEN
DRYING/HEATING
SCREENING
MINERAL FILLER
MEASURING
MIXING
MEASURING
COLD BIN
STOCKPILED AGGREGATES
1
2
3
4

(b) Schematic Diagram

Fig. 6.8. A Typical Batch Plant

aggregate, and the mixture arrives on-site too cold for proper compaction. Over- heated aggregates, on the other hand, may burn the bitumen during coating, whichg will normally alter its chemical and physical properties. Guidelines on the manufacturing tempratures of aggregate, bitumen and the bituminous mixture for different penetration grades of bitument are given in Table 8.3, Chapter 8 of this manual.

6.5.3.5. Dust collector : For the prevention of air pollution as well as to reduce loss of fines upsetting design grading, the modern hot mix plants have a dust collection system. dust collectors are provided adjacent to and in conjunction with the dryer. They consist mainly of single or multiple shell cylinders place vertically in which a hot air stream drawn from the dryer exhaust by a fan system is injected tangentially into the collector shell which sets the air inside the collector into high velocity centrifugal motion (Fig. 6.9). The whirling motion of the dust-laden air throws the heavier particles to the bottom. If the collected dust is not needed or is not suitable for use in the bituminous mix, it can be removed from the collector as waste. If however, is is required to be reintroduced, provisions are made to return the collected dust back to the aggregate as it emerges from the dryer. A dust collection system may include more than one dust collectors, i.e., the system may have a primary collector and one or more final or secondary collectors. A modern, highly efficent system called "Baghouse Dust Collector" using fabric filters is shown in Fig. 6.10.

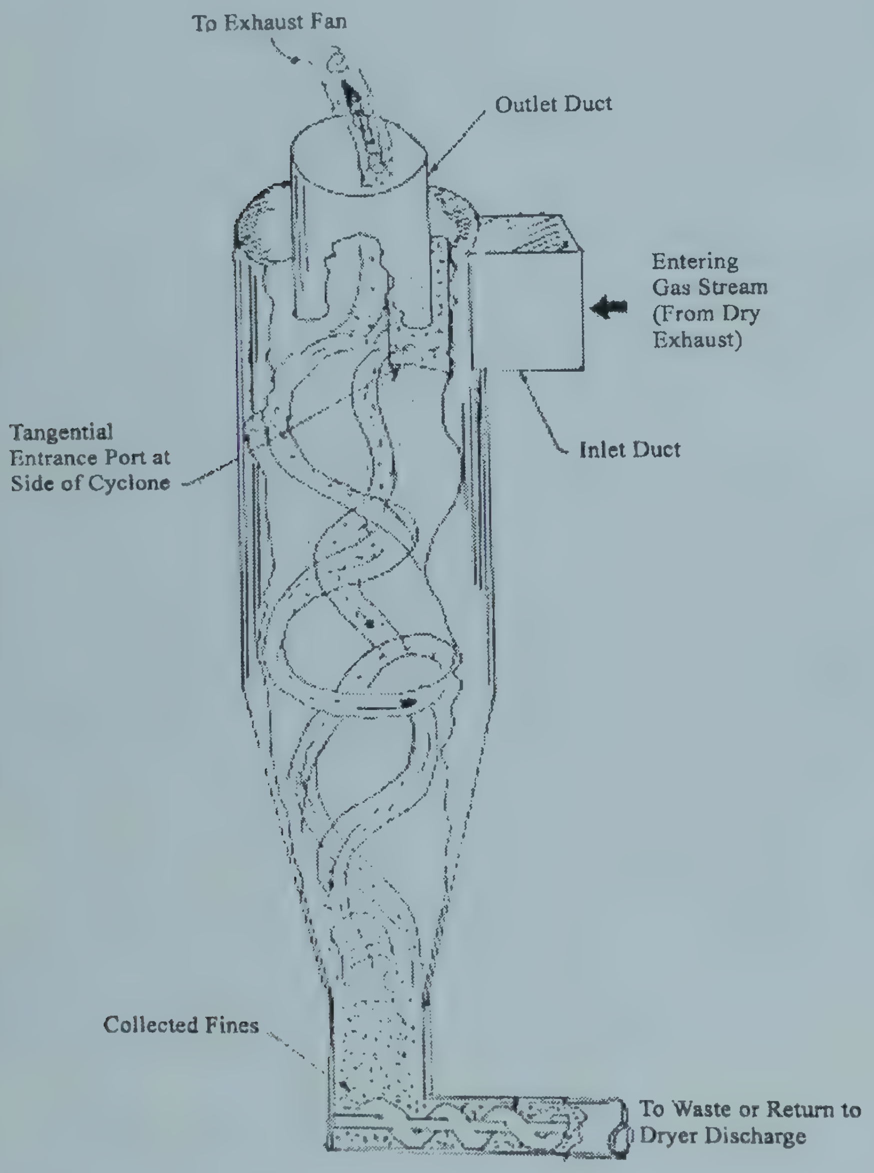

To Exhaust Fan
Outlet Duct
Entering Gas Stream (From Dry Exhaust)
Tangential Entrance Port at Side of Cyclone
Inlet Duct
Collected Fines
To Waste or Return to Dryer Discharge

Fig. 6.9. Cross-Section of Cyclone Dust Collector

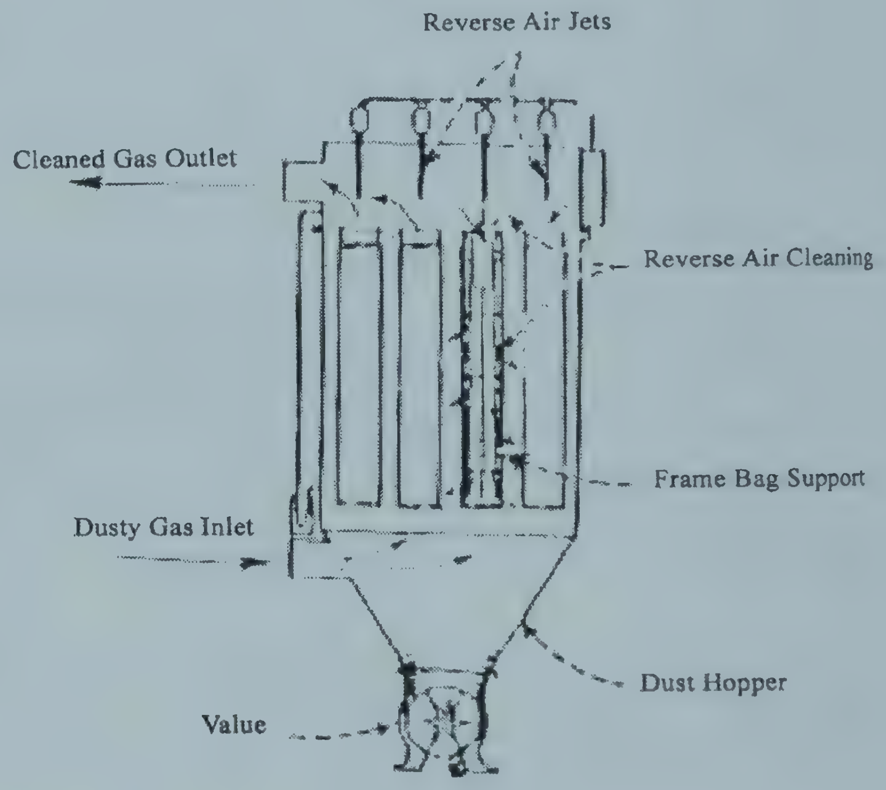

Reverse Air Jets
Cleaned Gas Outlet
Reverse Air Cleaning
Frame Bag Support
Dusty Gas Inlet
Dust Hopper
Value

Fig. 6.10. Baghouse Duct Collector

In regard to the dust nuisance as may be created at the plant site, conformity to the local norms is mandatory (See also ***Appendix 14*** 'Protection as of the Environment').

6.5.3.6. Hot elevators: These consist of a system of bucket elevators housed within a covered chamber. The length of run, the design of the buckets and the speed of the elevators should be, such as, to prevent loss of heat and loss of fines from the hot aggregates as they are elevated. Hot elevators are not needed in plants where the drum is located above the hot bins.

6.5.3.7. Hot screening unit : The hot materials carried by the elevators are discharged over a multi-deck (usually a 4-deck) vibrating table screen which separates the different aggregate fractions into the different hot bins. The top deck has an additional fixture to remove all oversize material which is discharged into a reject chute, provided for the purpose. In rotary screens, the production gets reduced; therefore, these may be used only where lesser output is acceptable.

They area of the screen tables should be adequate to deal with the in-coming aggregate from the dryer unit and also sufficient to feed the mixer unit to design capacity (neither under nor over- filling the hot bins). Normally, the screen capacity is designed to be slightly in excess of the full capacity of the mixer.

6.5.3.8. Hot aggregate bins : Hot bins are the temporary storage for the hot aggregates of different sizes. They have discharge gates opening at the bottom.

Each bin has an overflow chute. This prevents over-filling of bins where the cold feed calibration is incorrectly set. Without an overflow, the aggregates would back up into the screen discharge chute, and clog the screen, thus adversely affecting the grading and the screen unit.

The finer fraction of aggregates tends to build-up in the bin corners, and when released, results in excessive amount of fines, especially when the bin material has been reduced to a low level. This problem can be solved by welding filler plates in the bin corners to eliminate the 90° angles.

Hot bins must be must be emptied out at the end of the mixing process and the internal surfaces checked for any particles sticking to the sides. This requires regular maintenance attention.

Under ideal running conditions. the bins. should be constantly filled to mere or less the same extent. A bin brimming over with material side by side with a bin short of supply is likely to affect the efficiency of the plant.

The bins should be checked at regular intervals for defective or worn-out gates and plates. These defects will lead to leakage of material, particularly into the weigh hopper and distort the grading,

6.5.3.9. Filler silo: Filler material. where specified for use, is added separately to the mixer.

Because of their fineness and special packing characteristics they are considered to be one of the most difficult materials to handle.

In a well organised plant, the filler is stored in a separate silo and fed through a worm screw feeder into a weigh-hopper connected to a weighing scale with dial indicator or digital output via a load cell, The feeder should be interlocked with the aggregate and bitumen feed devices (Fig 6.8).

Both the filler silo and the weigh hopper are fitted with a rotating vane at the bottom for smooth flow of the fine material.

After weighing the hopper discharges the material into the mixer, generally after the bitumen binder has been admitted into the mixer.

6.5.3.10. Bitumen supply arrangement : The bitumen supply arrangement consists of the following:-

(a) **Bitumen Storage Tanks:** For supply of bitumen there will generally be bitumen storage tanks, or sometimes a number of bitumen boilers, maintained at a proper temperature. The total capacity of the tanks should be such as to keep an uninterrupted supply of bitumen for the period between supply renewals and also for an additional contingent period (of at least one-day) in case there is a delay in arrival of supply. Individual tanks are usually 30 tones to 50 tonnes capacity, and typical total storage for a 50 to 100 tonnes per hour rated output hot mix plant is 200 tonnes. The storage tanks must be calibrated so the amount of material remaining in the tank can be determined at any time.

The storage tanks must be free of water, fuel oil or any other foreign substance and also of traces or remnants of other grades of bitumen grades of bitumen than the one in use on the job. The tanks and all pipes and fittings must be properly insulated and the bitumen in the tank maintained at the proper temperature by heating. There should be thermometers to check the temperature so the no over-heating or burning takes place.

(b) **Bitumen Heating and Circulation:** Bitumen has to be heated to render it fluid enough for movement through the delivery and return lines. Heating may be done by the circulation of steam or hot oil through coils in the tank, or it may be done electrically.

There should be bitumen circulation lines of adequate capacity running through the feeding and storage system. The bitumen tanks, supply lines, and weight buckets for the batch plant should be properly jacketed for heat insulation. Return lines discharging (unused binders) back to the storage tanks should be connected to the bitumen tank below the bitumen level in the tank to prevent oxidation.

The bitumen discharg bucket at the pug mill should be of such a shape and construction that it can discharge quickly, in a uniform thin sheet or in a number of streams spaced over the whole width of the mixer, to eliminate chances of non-uniform mixing within the mixing cycle time.

Preferably, the bitumen should be discharged across the whole width of the mixer box. Also, it should be discharged transversely to the rotation of the material within the mixer.

(c) **Bitumen metering:** For each batch, bitumen may either be pumped into a special bucket of known weight and weighed on a scale or it may be measured by a meter. When metering device is used, a volume measurement is made. By way of calibrating a meter, the volume of bitumen pumped in between two readings is weighed.

6.5.3.11. Measuring and mixing of aggregate and bitumen : In a batch mixing plant, the aggregate is drawn from got bins in predetermined amounts and dropped into a pug mill mixer in batches. Then, the required amount of bitumen is added and mixed with aggregate. After thorough mixing in the pug mill the final mix is discharged into a truck or taken to a storage silo The various sub-components in the preparation of the final mix, ready for transportation to the site are as under :

(i) **Aggregate weigh hopper :** From the hot bins, the aggregates are released into the weigh hopper starting with the largest size and going down to the finest; filler is the last to be added. Depending on the size of batch and the proportioning of a material to be blended with material from other bins the amount of each bin is determined. The weigh hopper is suspended from scale beams and the amounts of aggregate are cumulatively weighed. It must be ensured that the hot bins have sufficient material for a complete batch; if not, an adjustment in the cold feed is indicated.

(ii) **Bitumen supply Arrangement**, as detailed in para 6.5.3.10.

(iii) **Mixing in Pugmill Mixer :** In all modern batch mixing plants, the mixing of aggregates, filler and bitumen is carried out in a pugmill mixer. The pugmill mixer contains a pair of revolving shafts with paddles fixed to them. The paddles have a common intermeshing area during the mixing process. The paddles consist of paddle shanks and paddle tips which are attached at an angle to the axis of the shaft so that a horizontal movement and tossing action are imparted to the mixture constituents as well as a vertical mixing action. pugmill operation is his shown in Fig. 6.11.

The pugmill mixer is mounted directly beneath the weigh box and bitumen bucket and should be high enough so that it can discharge the mix directly into the hauling truck.

While some amount of dry mixing takes place during the deposition of materials in the weigh hopper and also when these are deposited in the pugmill, the wet mixing starts with the flow of bitumen from the bucket or meter.

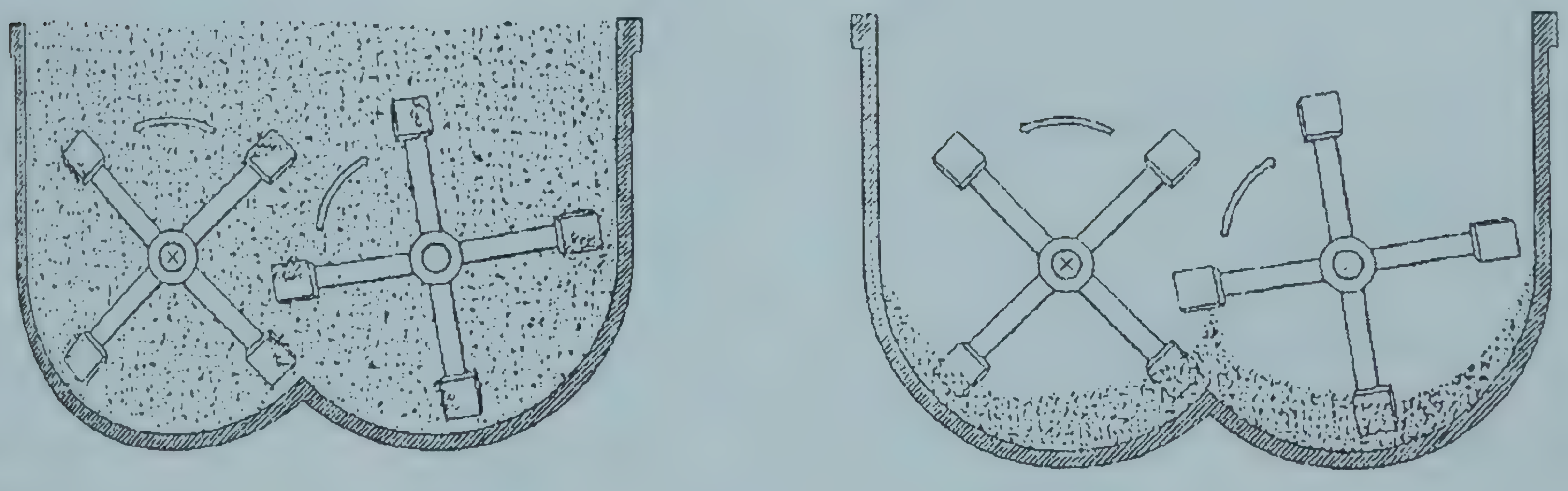
It is to be borne in mind that the mixing time should not be any more than what is required to obtain a uniform coating of bitumen on all aggregate particles, otherwise the bitumen film tends to harden as a result of exposure to air and heat.

The final quality of the mix is directly influenced by a number of features of the mixer including:

- the shape and size of the paddle tips
- the clearance available between the paddle tips and the jacket linear plates
- the speed of the mixing shaft
- the duration of mixing

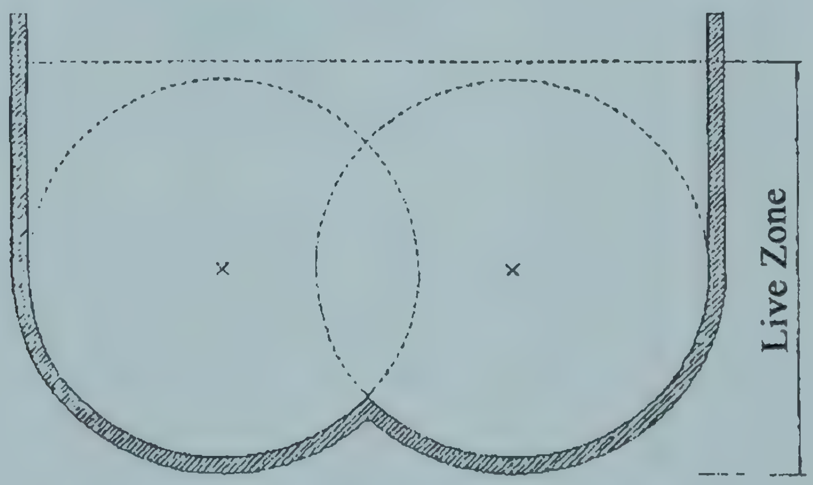
- temperature of material and
- the level upto which the pugmill chamber is filled with material above or below the "live" zone (see Fig. 6.11)

After the mixing operation has been completed, the final mixture is discharged from the bottom of the pugmill mixer directly to the hauling truck below or taken to a hot storage silo for temporarily storing the mix, before haulage.



Overfilled Pugmill

Underfilled Pugmill



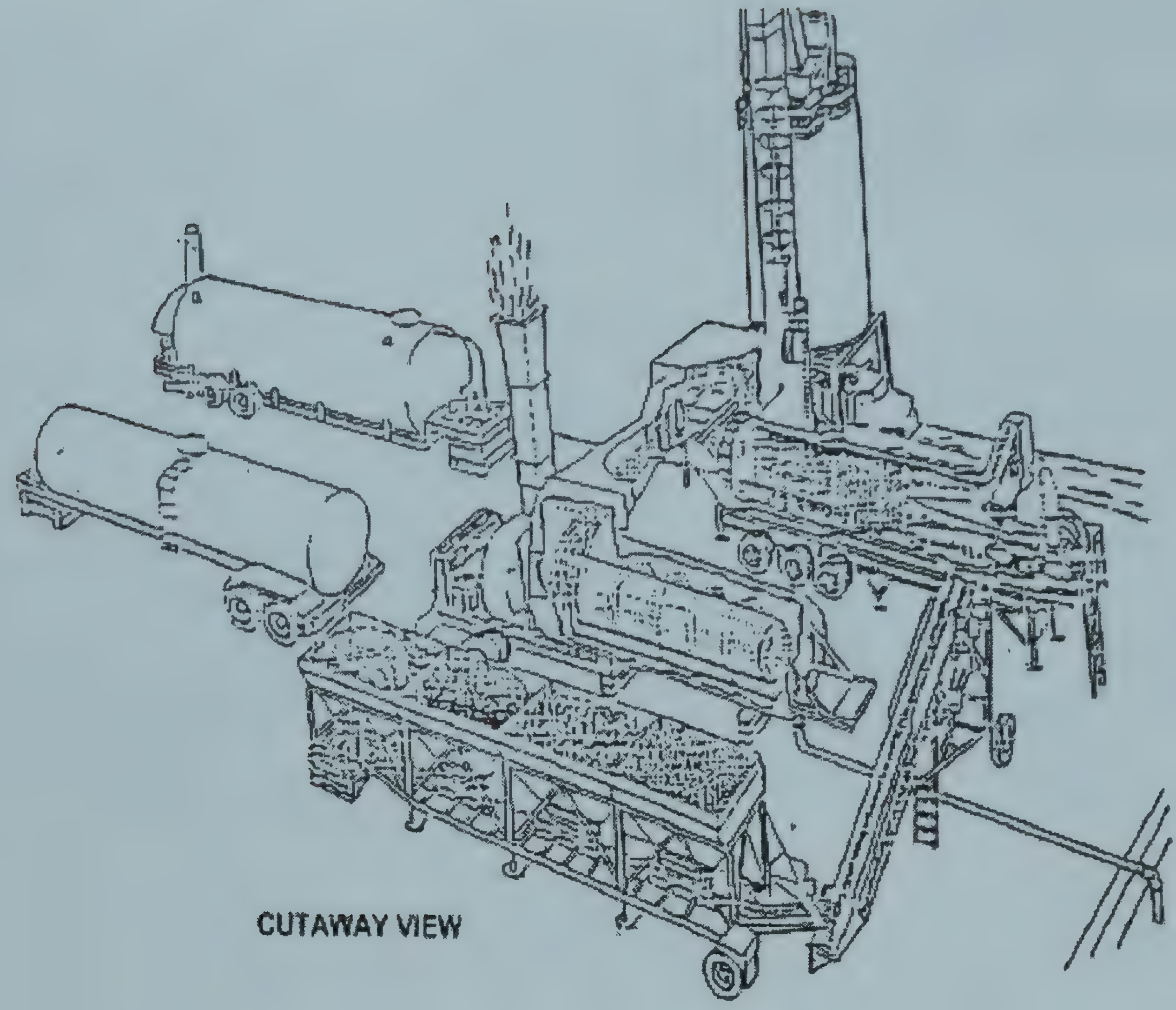
Pugmil "Live Zone"

Fig. 6.11. Pugmil Operation

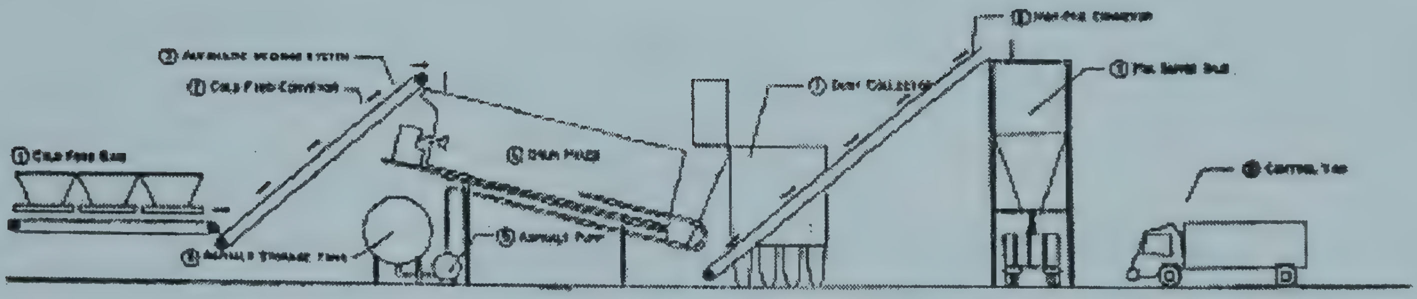
6.5.4. Components of a drum mixing plant

6.5.4.2. General : When compared to the Batch Mixing Plant described in para 6.5.3. the Drum Mixing Plant is without the hot aggregate screens, hot aggregate screens, hot bins and pugmill mixer. It only consists of a cold aggregate feed system,, a rotating drum mixer with modified flights, a bitumen supply system, a dust collector system and a surge silo (Fig. 6.12).

6.5.2.2. Drum mixer : The drum mixer not only dries the aggregate but also blends the aggregate and bitumen into the designed mix. The heating unit or flame is at the upper end of the drum and the cold aggregate enters the drum at the flame end. Thus, the aggregate and the hot air flow in the same (parallel) direction unlike the batch mixing plan dryer where the aggregate and got air flow in opposite directions. The drum mix system essentially depends on a calibrated cold feed flow to maintain the job mix grading. The gate opening and feeder setting for each bin control the cold feed from that bin. The belt feeders are driven by a variable speed electric motor. The materials are then fed onto a main conveyor belt, generally with electronic load sensors. There are sensors to determine the moisture content of aggregates so that, wherever necessary, adjustments can be made in the proportioning of material.



CUTAWAY VIEW



SCHEMATIC DIAGRAM

Fig. 6.12. Typical Drum Mix Plant

There is a dust collector which can feed back the collected material whenever required and there are means for sampling various components of materials while the plant is in operation. There are automatic burner controls and sensors to measure the temperature of the final hot mixture at the point of discharge.

6.5.4.3. Design improvements in drum mixer : There have been a number of modifications in the conventional design outlined in para 6.5.4.2. These are as under:

(i) In this modified design, Fig. 6.12 (a) the aggregate and hot air flow in opposite directions, the burner being located in the drum at the end opposite to the entry of the aggregate. the bitumen and recycled asphalt material (RAP) are introduced at a point behind the burner flame where the maerials are not exposed to high heat and exhaust gases.

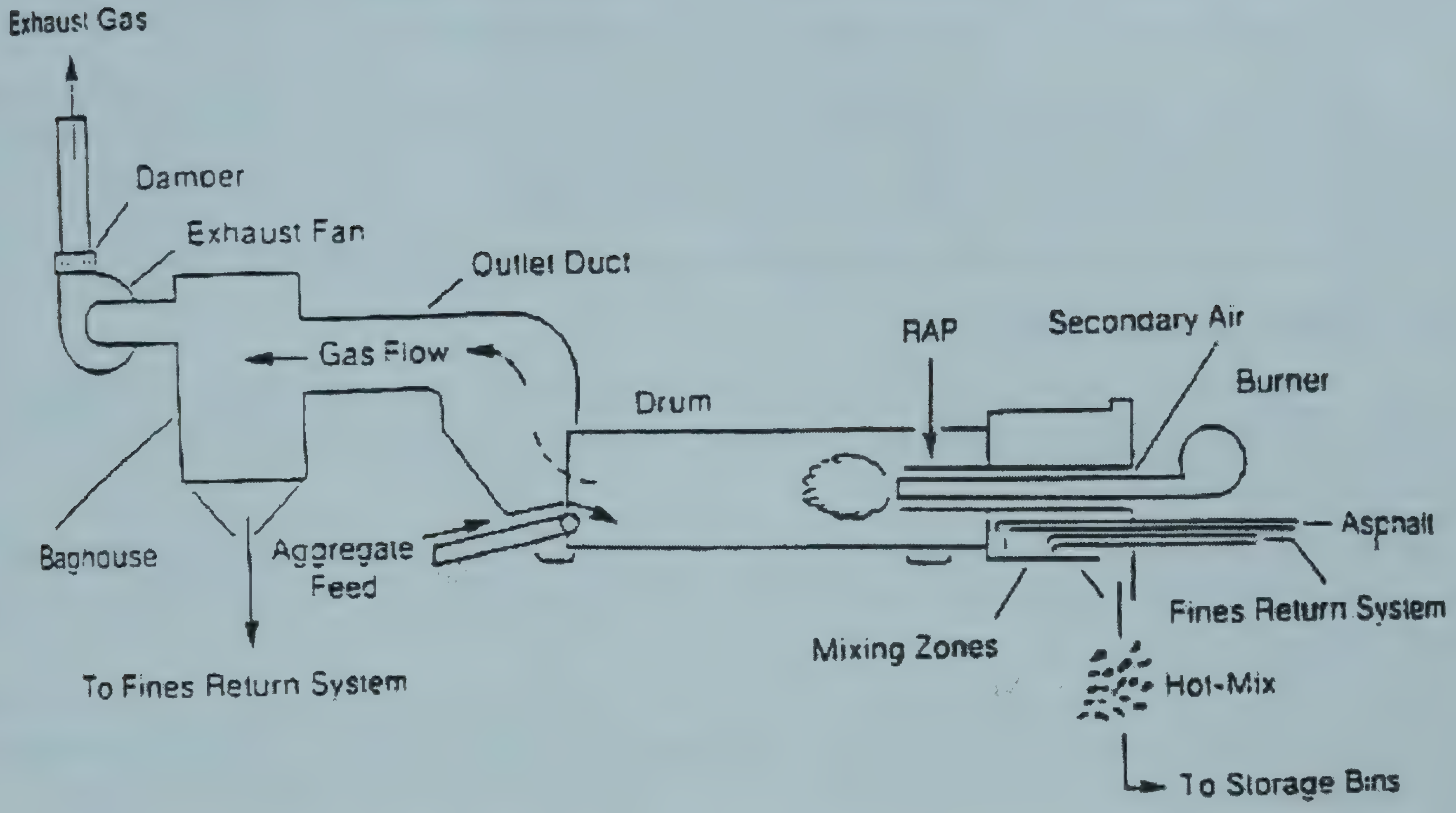


Fig. 6.12(a). An Improved Design of Drum Mixer: Counter Flow Type

(ii) In the double drum plant, there are two different drums; the first drum is for drying and heating of aggregate and second drum is used for mixing of bitumen with the heated aggregate.

(iii) In the double barrel drum mix plants, there are two coaxial drums. The aggregate is dried and heated in the inner drum and thereafter material comes out to the outer surface of the inner drum which has paddles and acts as pug mill for mixing of the bitumen and hot aggregate, thus mixing them in outer drum. The entire process of ;such drum mix plants gives a very homogeneous mix. Such plants are very popular in U.S.A.

6.5.4.4. Storage of hot mix : In a continuous plant, like, the drum mixing plant provision of surge or storage bins is an absolute necessity. Through a conveying system, like, belt conveyor or bucket elevators a surge bin is connected to the plant for purposes of holding the hot mix for relatively short duration of a few hours. A surge bin need not be insulated because of a relatively short storage period However, a storage bin where hot mix is to be stored for longer durations, needs to be insulate. Both surge and storage bins are cylindrical in shape with a conical bottom.

6.5.5. Selection of the appropriate type of plant : Over the years, there have been several improvements brought about in the design of drum-mix plants. The relative advantages and disadvantages of drum-mix plant in comparison to a batch mixing plant are as under:

- with continuous operation in a drum mix plant, the variations in the mix composition and temperature associated with frequent “starts” and “stops” of the batch mixing plant are minimised.
- From the environmental angle, the extra air pollutants emitted, each time the plant "starts" are minimised in case of drum mix plant, in comparison to a batch mixing plant which has more frequent "starts" and "stops".
- The productivity of the hot mix is significantly increased by the continuous running of a drum mix plant during normal working hours and not just when trucks are available for loading as in a batch mixing facility.
- A drum mix plant can begin producing the hot mix earlier in the morning before roadway conditions permit the placing of the hot mix.

- The control of grading of aggregates in the mix in a batch mixing plant is superior to the control in a drum mixing plant, which depends for the correct proportioning, only on the cold feed system.
- Thoroughness of mixing at controlled temperatures in a pugmill mixer or a batch mixing plant is of a higher order than in a conventional drum -mix plant, where the heating and mixing take place in the same drum there being no separate dryer. However, in some improved designs of a drum -mix plant, a coater unit has been introduced.
- The drum-mix plant is quite suitable where recovered asphalt pavement material is to be recycled into the got mix.

6.6. Material Transportation Trucks

6.6.1. Type of vehicle : paving mixtures are hauled in trucks. While too small a vehicle may be uneconomical, a vehicle too big in proportion to the volume of the charge carried may lead to quick cooling and segregation by cone formation.

The box of the truck should preferably have rounded edges and the vehicle should be equipped with a hydraulic hoist for elevation of the tipping body enabling automatic gravity discharge. The box and the bed should be tightly sealed and leak proof.

Before receiving the material charge from the plant, the bed and the sides should be clean and free from lumps of cold material or seepage of bitumen from previous trips, petroleum oils, solvents, dirt or any other deleterious material. A thin coat of diesel is used to coat the box, to prevent the bituminous material sticking to the truck.

6.6.2. Cover: There should be an adequate cover of sufficient size and proper insulating quality to protect the entire load from dirt, foreign material and heat loss. the cover is generally a tarpaulin, or suitable sheet of heavy canvas.

6.7. Asphalt paver Finisher

6.7.1. Function of paver: the basic function of a paver is to spread the bituminous mix on the existing surface in a uniform layer, at pre-determined with to the desired thickness or level and to required smoothness, all ready for final compaction. Eventhough the modern pavers are getting to be more and sophisticated, the basic function remains the same.

The functioning of a paver is schematically shown in Fig. 6.13. The bituminous mix from a tipper lorry is discharged into the receiving hoper in the front portion of the paver. The mix is carried along the conveyor, through flow control gates, to the augers which distribute the material in front of the screed, to the full width of the screed. Cutting down or extending the normal width of the screed unit can be accomplished by installing 'cut off-shoes' or 'extensions' as the case may be, to the screed unit . The height of the bituminous mix in front of the screed needs to be maintained at a constant level. The settings of various parts in the system of flow of bituminous mixture are governed by the thickness of the mat, the width of paving and travel speed of the paver. As the paver moves forward its tractor pulls the screed into the deposited bituminous mix and the screed seeks the level where the path of its bottom surface is parallel to the direction of the pull.

It is important to ensure in the case of hot-mix hot-laid bituminous mixes that the laying temperature is not lower than the minimum laying temperatures given in Table 8.3 for different penetration grades of bitumen used.

Modern paving machines are capable of laying bituminous mixes from 2 m to 12 m in width, 20 mm to 200 mm in thickness with a working speed of 3 m to 30 m per minute.

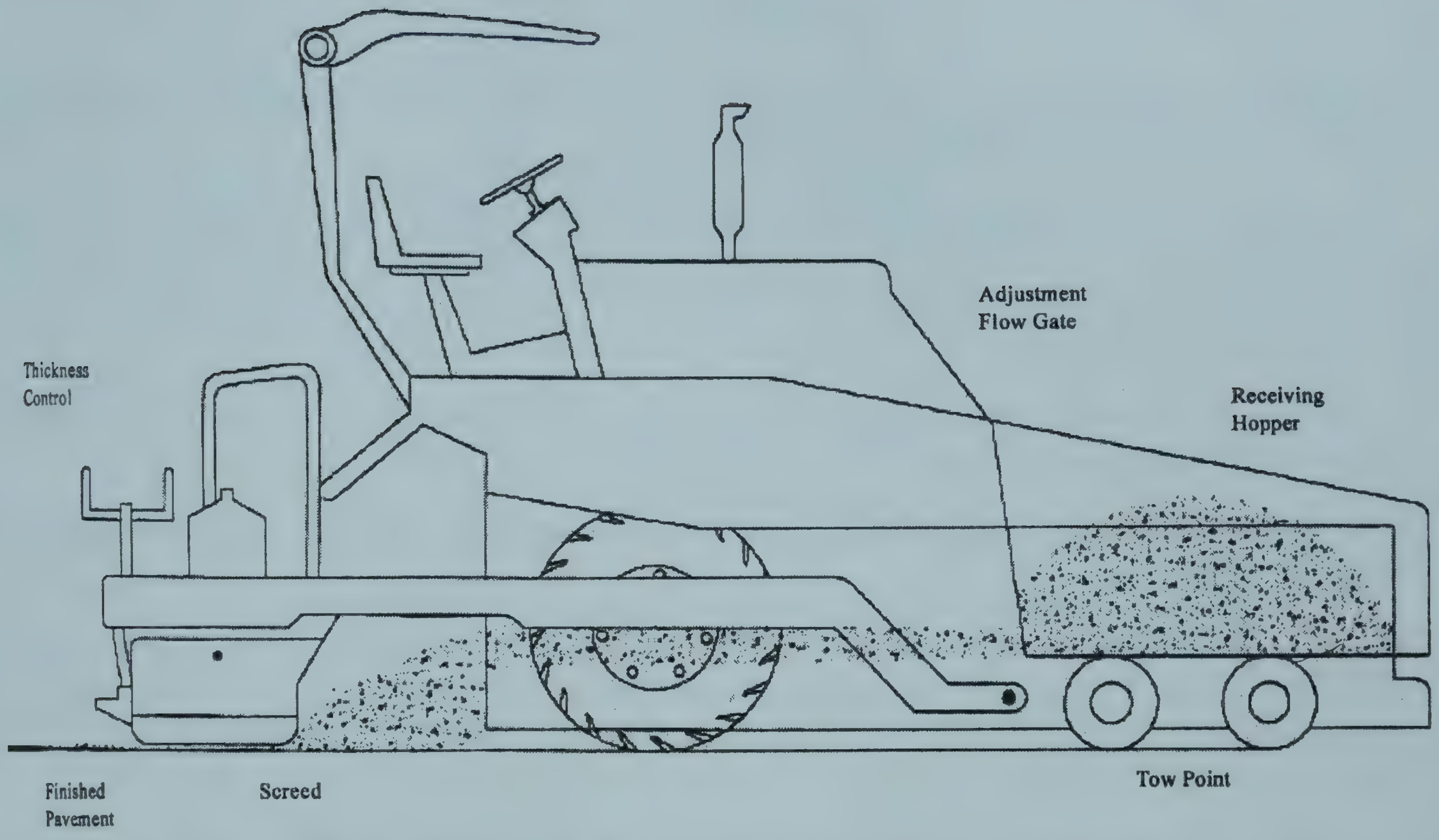


Fig. 6.13. Schematic Diagram of Flow of Bituminous Mix in Asphalt Paver Finisher

6.7.2. Types of pavers: The paving machine may be crawler mounted (tracked) or equipped with rubber tyres which permit a greater degree of freedom for movement Although, most modern pavers used for bituminous works are constructed with rubber tyres, with two or four large driving wheels, almost all manufacturers can provide alternative crawler-mounted models.

The crawler-mounted machines are more stable and can support greater width of screed. The screed width can be extended upto 12 m. A tracked machine will perform better when laying on unbound material layers, such as, crushed stone base, where a tyred machine tends to lose traction and the wheels ding themselves into the loose material.

Tyred machines have greater mobility and travel faster when in transit between work sites, with a greater degree of manoeuvrability. The screed width may, however, be limited to 8 m. They are very efficient when working on top of a firm layer which may often consist of a previous bituminous course, or the esisting highway surface, on which an overlay is to be placed. With tyred paver there is little chance of leaving a track mark or indents on the surface, which might happen with a tracked machine.

6.7.3. Components of a paver: Broadly, the paver finisher may consist of three components:-

(a) The tractor unit
(b) The hopper unit
(c) The screed unit

These are briefly described in succeeding paragraph.

6.7.4. The hopper unit : the hopper is the receptacle for receiving the mixed material from a tipper truck. In the case of rubber tyred paving machines the load of the hoper unit is borne separately on its own solid rubber tyres. In front of the hopper, there is a pair of free running push rollers which remain in contact with the rear tyres of the delivery truck.

The tipper truck should deposit the mix in the receiving hopper over a period of time in a steady flow while the paver is still in motion, slowly pushing the truck ahead of it .

When mixed material sticks to the sides of the hopper it may require to be manually disengaged since the accumulated material cools quickly and comes out in lumps giving a rough non-uniform texture to the surface. The lumps may also clog the ends of the auger prevent side spreading. These days most paver models have hydraulically operated hopper sides which, when worked by the operator, fold upwards to discharge the mix onto the slat feeders.

To facilitate winter working, the hopper sides may be insulated by means of fixing hard wood boards so that the material does not cool in contact with the hopper sides.

In some crawler pavers the hopper unit is mounted on the same tracks and more or less forms a part of the tractor unit.

6.7.5. The tractor unit : The tractor unit is carried on the drive wheel and contains the twin slat conveyors built with articulated steel strip components to carry the material from the hopper in front to the augers (screws) for spreading the material at the rear of the machine. The unit also carries the automotive power unit, the fuel tanks, the drive controls and the operator's seat.

Most pavers have dual seats and dual controls, one on each side of travel, so that the driver can operate from either side as necessary.

The hopper is sometimes fitted with control gates at the back opening on to the slat conveyors. Each setting of gate opening and slat conveyor speed can be independently controlled by the driver.

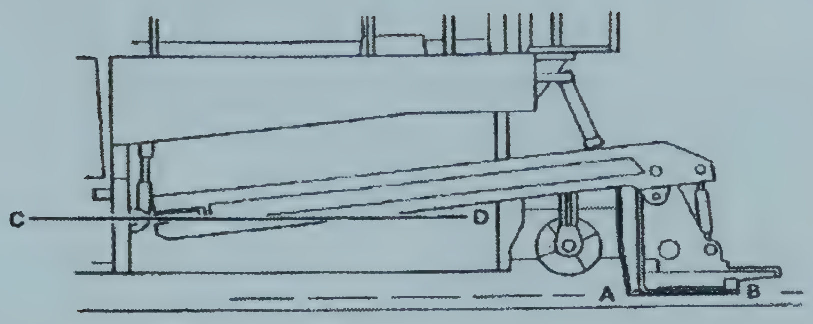
The slat conveyors deliver the material to the augers or spreading screws. The rotation of the screws is synchronised to the speed of the corresponding conveyor. It distrbutes the material laterally along the length of the screed to maintain a constant depth of material in front of the screed.

The vertical level of the auger is variable and can be adjusted, within a range, for different thicknesses of laying by controlling the flow. The adjustment to correct auger height requires experience as its level is critical to the quality of mat.

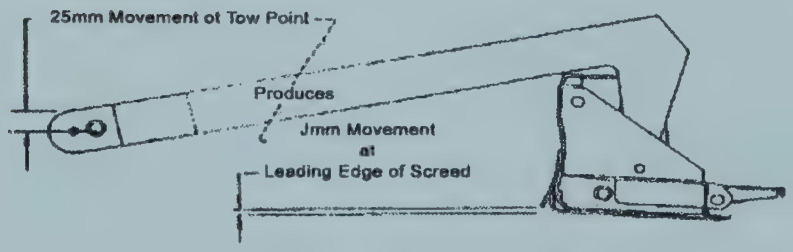
6.7.6 The screed unit

6.7.6.1. Description: The paving element of the machine is the screed, which is a self-levelling float mechanism whose function is to lay the material (sometimes referred to as the mat) to the specified (loose thickness (Fig. 6.14) This function is realised mainly through the help of a pair of long levelling arms connected to freely-moving hinge--points (pivots) on either side near the central part of the body of the tractor, much removed in space from the point of action of the screed. The pivot is also the tow-point for the tractive force for the screed.

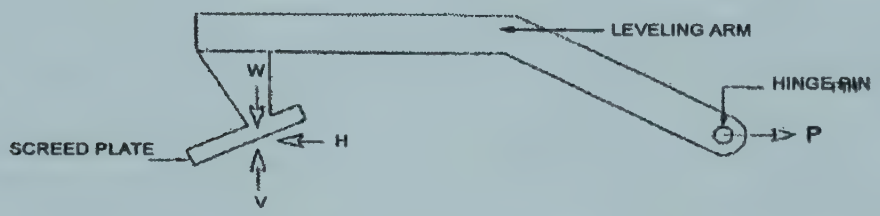
Except for its attachment to the tow point (Pivot) to transmit the tractive force of the paver machine to the levelling arm, no part of the arm or the screed is actually supported by the machine. The entire weight of the screed is carried by the mix material which is being laid. when pulled in the direction of travel aginst the material deposited in front of the screed, floating freely on its forward pivots, will seek a level at which the path of its flat bottom surface will be parallel to the to the direction of pull.



(a) ACTION OF A FLOATING SCREED



(b) EFFECT OF CHANGING THE HEIGHT AT THE TOW POINT



(c) FORCES ACTING ON A SCREED

P PULL
W WEIGHT OF SCREED UNIT
H HORIZONTAL RESISTANCE ON SCREED PLATE
V VERUCAL RESISTANCE ON SCREED PLATE

Fig. 6.14. Screed Unit

As it is, at the central point of the vehicle where the levelling arm is pivoted, the vertical fluctuation in level caused by surface irregularities is minimum. In addition, the geometry of the lever arm is such that the screed point has a long reaction time. Rapid vertical movement in the tractor unit is reflected at the screed to the extent of only about to the extent of only about 15 per cent. If the vertical movement is maintained, movement in the screed becomes about 85 per cent after it has travelled two lengths of the side arm and to the full extent only after another three lengths run provided the cause of the change is still present. The delayed action, thus, stretches out the variation over a considerable length and if the variation is for a very short duration, say passing over a raised manhole cover, the effect at the screed is negligible, and an acceptable finished level is obtained.

This delayed action mechanism can be improved by the anticipation of the screed operator (or screw man) as the thickness adjustment requirement can be anticipated by the operator much in advance of its actual point of occurrence, and suitably adjusted by sensor control. The period of anticipation may vary from machine to machine but generally at a medium speed of travel it is usually about 4 metres before the point at which the vertical change will take place.

Fig. 6.14 also shows in broad terms, the various forces acting on the screed mechanism.

The tractive force of the machine comes as a pull P to the levelling arm, which in turn gives rise to a horizontal resistance H at the screed mix contact point. When P exceeds H, the screed starts moving in the direction of travel.

The angle that flat bottom of the screed makes with the horizontal plane at the material surface is referred to as an 'angle of attack' The angle of attack can be manipulated by ether the driver, by raising or lowering the pivot tow-point with respect to the road surface, or by the screed operator, working the screed screws situated at each side of the screed. Both of these actions alter the tilt of the screed plate, thus changing the thickness of the mat.

As soon as the screed is tilted up towards the material material heap, more material is admitted under the plate and the vertical uplift V exceeds the weight W resulting in the rise of the screed plate and increase in the thickness of the mat. With rise in the screed plate V starts decreasing and ultimately again becomes equal to W in equilibrium. Then the vertical movement ends and the screed plate once again starts moving parallel to the direction of pull maintaining the new thickness thus achieved.

For decreasing the thickness, a reverse procedure is followed with a tilt down in the angle of attack.

From the description of operation given above, it can be seen that the working of the screed is a continuous process of keeping all the operating forces in equilibrium. However, since these operating forces are very sensitive to various other influences, there is an over-riding need to keep all of them at least in a stable uniform configuration. Hence, the need to keep the flow-gates set at a properly adequate opening; to keep the slat conveyors moving uniformly, to keep a uniform height of material in front of the screed, and to keep the temperature of the mix uniform so that changes in viscosity do not occur and alter the forces of resistance. This is a highly skilled operation, and should only be performed by experienced personnel.

6.7.6.2. Screed Functions: The various functions that the screed unit performs are summed up as:

- striking off the material deposited by the screw,
- level it to required (loose) grade,
- partially compact it and iron out to a smooth surface, and
- shape the surface to crown and cross-fall formation.

The main elements of the screed unit to help in carrying out the above are:-

(i) the screed plate
(ii) the heating system
(iii) vibrators and tampers and
(iv) side plates to box and contain the material
(i) screed plate

Normally, the screed plate is adjustable at the centre. It can be adjusted to lay two different crossfalls, forming a "crown" or set straight to lay a crossfall. The inclination of the screed plate can, therefore, be controlled in half-widths. Also, the leading and the trailing edges of the screed plate can be provided with independent crown adjustment.

For normal runs, the crown screws can be interlocked by a chain arrangement so that a single lever movement adjusts the leading and trailing edges to a uniform specified crown. If, however, a slight additional crown is required in the leading edge, for better surface profile, they can be made independent and adjusted separately during paving. The available range in the screed adjustment device allows for a slight inclination.

In actual practice, generally, the leading edge of screed is provided with slightly more crown to ensure better flow of material up to the trailing edge. Provision of too pronounced a crown in the mat, however, is discouraged. A more economic and easy alternative is the accomplishment of the required profile in the original layers below it (in less costly material) over which the paver simply lays a more or less uniform mat.

Pushing a screed inclination with a pronounced crown through a uniform material heap results in moue vigorous shoving and less flow under the screed plate at the lower edge leading to segregation of larger sized aggregates at the edge and a rough open-textured surface at the edges which makes the mat more vulnerable to edge-breaking.

Superelevation or normal crossfall work can be provided in the profile by adjusting both halves of the screed to the same required slope.

In most pavers it possible to adjust the crown on the screed from 10 mm negative to 50 mm positive.

(ii) The screed and the tamping unit need to be kept heated so that they do not pickup mix material during working. This may be done by an electric coil or by diesel fired or propane gas burners.

(iii) In order to provide a smooth surface for rolling, and to provide some initial compadtion, the screed plate is equipped with :

- a vibrating device or
- a tamping device or
- a combination of both i. e. , a vibrating and tamping arrangement

Screed vibration is effected either by electric vibrators or by eccentric loaded rotating shafts. Vibration is provided to the entire bottom-plate, generally on a high frequency rage with a small amplitude.

The combination screed claims the advantages of both to an extent. In tamping and vibrating screeds as a general rule, it is desirable to maintain a ration of 2:1 vibrator to tamper speed since to much of vibration causes the bitumen in the mix to rise upto the surface of the layer (i.e., 'fatting up'). In some of the modern makes, 'high compaction screeds' have been developed with a view to reduce the likelihood of rapid cooling and decreased reliance of subsequent compaction. In such 'high compaction screeds' improvements, like, doubling the tampers, increasing the amplitude of vibrators and introduction of a system of pressure bars have been brought about. For example, at a paving speed of 300 m/hr and a frequency of 70 Hz the pressure bar advance is around 0.2 mm in 0.007 seconds. Thus, the rapid acceleration and high frequency impulses lead to much greater degree of compaction compared to conventional pavers. Depending on the design of combined vibrating and tamping screed, the achievable degree of compaction may be in the rage of 80 to 90 per cent.

(iv) The screed is provided with side plates, which confine the material width being laid.

6.7.6.3 Performance: Although, various factors have their subtle influence of the final quality of the paving work done by the screed, the main factors directly influencing its performance are

- the speed of the paver machine,
- the depth of material in front of the screed, and
- the angle of attack

(a) Speed

The speed of the machine has a direct influence of the thickness of the mat and even with an unaltered angle of attack a very fast speed will lay a slightly thinner layer of material than will a slower speed.

Variation in speed will also be the cause for differing degree of exposure to pre-compaction effort provided b the tamping/vibrating device with consequent effect on thickness.

(b) Depth of material

The depth of material in front of the screed gas a direct effect on the screed because this affects the horizontal resistance against movement.

The depth of material in front of the screed should be uniform across the width of the screed and also maintain at a constant level with forward movement along the direction of travel. As the levelling action of the screed is dependant on the balance of forces acting on the screed, any change in their magnitude will be reflected in the upward or downward movement of the screed.

If the depth of material against which the screed has to push increases, in order to overcome the increased resistance the screed tends to rise, causing the formation of a ridge line at that point which will be difficult to remove afterwards by rolling. Cooling of the mix in front of the screed due to stoppages has a similar effect.

Conversely, when the depth of material falls, the screed sinks in the mix in the absence of adequate material resistance, causing decrease in thickness and the formation of a dip-line.

It becomes the operator's duty to control the speed and also ensure that the spreading screws are working under a more or less constant head of in-coming material to lay a level mat.

(c) Angle of Attack

Manipulation of the angle of attack as per the requirement of the situation is the job of the person attending to the screw. Achieving correct result requires the attention of a highly experienced and skilful ‘screw-man’, since the mat is required to be laid not only with a smooth regular surface and uniform thickness of mat on a not so regular surface but also to have a design surface level within the specified tolerance (generally, 3 mm to 6 mm) Also, the final tolerance test will not be on the paved surface leveled by the screed but on the rolled surface, where the difference in compacted level will also be a function of the varying loose thickness of the material laid. The screw-man has also to take this into account.

One way to help reduce the problem is to see that all major surface irregularities and spot depressions, etc. are rectified while preparing the surface, prior to laying, so that the receiving surface is as regular as possible.

6.7.6.4. Paver controls: In recent years, more sophisticated controls particularly electronic sensors and hydraulic screed adjustments have been introduce by manufactures. Manual screed adjustment is now replaced by semi-automatic or automatic screed control.

Thus, paver control may be by :

- Manual control,
- Fixed level control, or
- Moving reference control

(a) Manual Control

Sometimes, in case of a wearing course construction on a newly laid mat or the construction of a strengthening mat on a recently laid surfacing finished to correct grade and crossfall, only manual control may be specified. In such a case it has to be ensured that the screed level controls, once set, and the output seen to have the desired profile, should remain fixed with only minor adjustments when considered necessary by the operator.

(b) Fixed Level Control

The underlying principle in this case is that if the screed control can follow the reference of a string-line or wire set to the correct level, then a smooth pavements surface will result irrespective of the actual irregularities in the surface of the receiving bed on which the paver wheels are operating .

Fully automatic electronic pavers may be equipped with a grade sensor, a pendulum arrangement, a command panel and a motor or cylinder device to manipulate the screed tilt.

The grade sensor or ‘the follower’ is usually a flat rectangular metal skid 300 mm x 25 mm or a triangular piece of metal plate connected to a frame-work with spring -backing (for continuous contact with the grid) attached to a pair of micro-switches (one signalling rise and the other fall of the grid) sending reference instructions to the control box for hydraulic drive. (Fig. 6.15.).

The grade sensor gets its instructions from the string line (grid) set parallel to the design grade, generally placed on the side of the paver. Slope of transverse profile is monitored by a pendulum adjusted for a particular slope. In addition, there is the command panel for manual instructions, if any.

The grade sensor, the pendulum, and the command panel feed instructions in the form of electric impulses to the control box for the screed, which activates the hydraulic cylinder fixed to the screed. The screed is thus, controlled by the final level required and is essentially irregularities of any irregularities in the existing surface.

(C) The Moving Reference Control

The electronic sensor is a sensitive piece of equipment. However, setting up and maintaining a wire line to correct

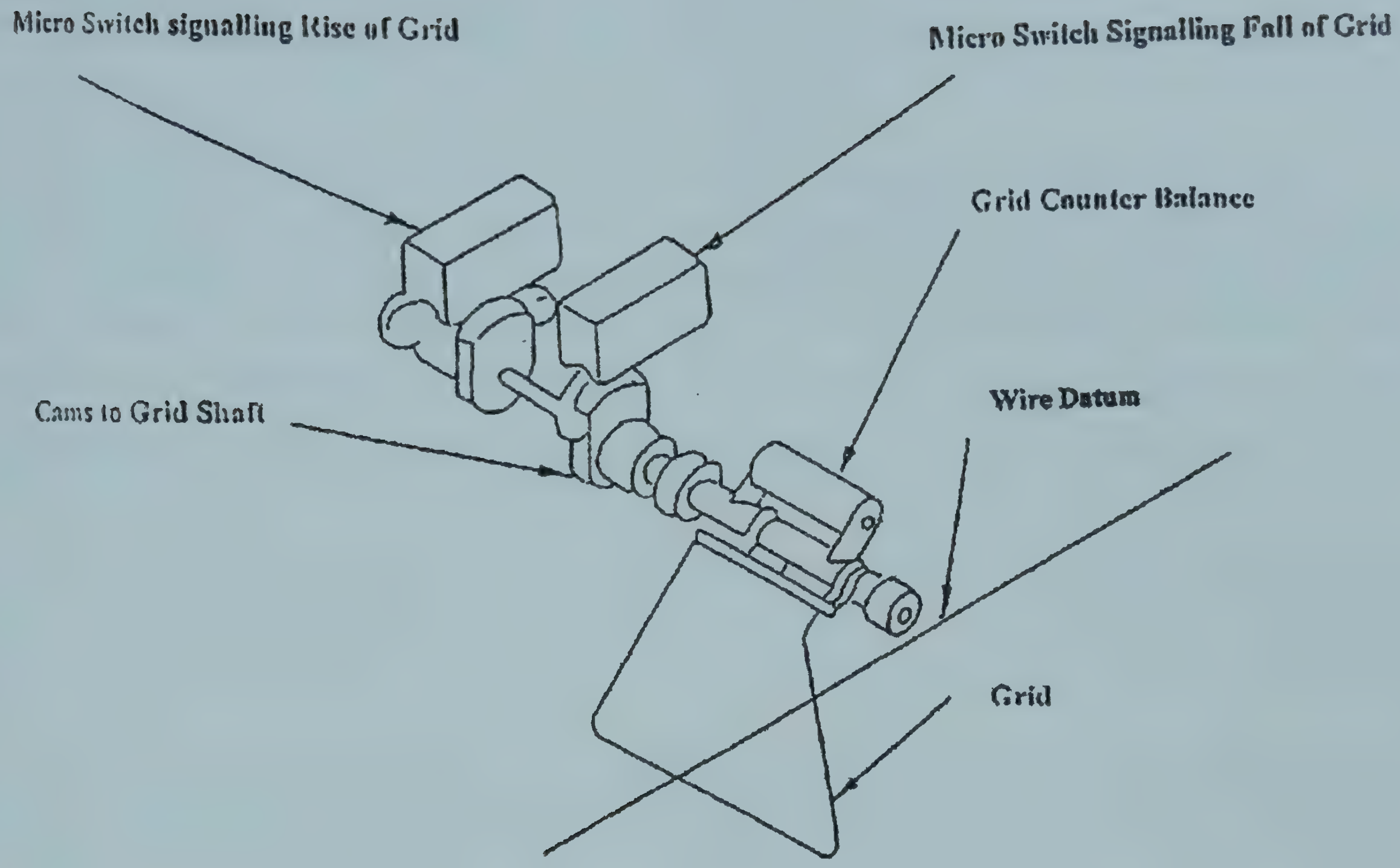

Micro Switch signalling Rise of Grid
Micro Switch Signalling Fall of Grid
Grid Counter Balance
Cams to Grid Shaft
Wire Datum
Grid

Fig. 6.15. Operation of Wire Sensing Device

level is a tricky and time consuming operation. In view of the above, on many sites it is considered adequate for the sensor to take its level information from a 'floating beam' or "ski" this ski is upto 3 m long resting on the adjacent surface of the road on which the electronic sensor rests it is hinged at the front and towed along by the machine. The ski may be set up to run of an existing herb, gutter or on an adjacent lane, laid to grade and profile, or on the existing road surface if it is at reasonable level and grade .

In actual practice, in multi-layer construction, it is considered more economical and easy to provide accurate level compensation by use of sensor in the lower or bas-course layers. After these layers are brought to tolerance, for achieving good riding quality in the final wearing course, the paving machine can be set for uniform thickness laying, no correction or re-construction being required in costly wearing course material.

This may be adequate for purposes of new construction, during which the quality of finish to the top of the layer underlying the bituminous construction can be carefully controlled. However, when the bituminous material is to be used to overlay an existing pavement, it is sometimes the case that the latter has deformed during its life to an extent that would be unacceptable if reproduced in the new overlay.

6.8. Compaction Equipment

6.8.1 The need for compaction: The principal means of achieving compaction in bituminous material is by rolling.

Compaction increases the material's load-spreading capability capability and its durability. By reducing air void content, and thereby ingress of water and air, it also enhances the performing life of the bituminous mat, reducing problems of stripping and brittleness due to oxidation in the binder material.

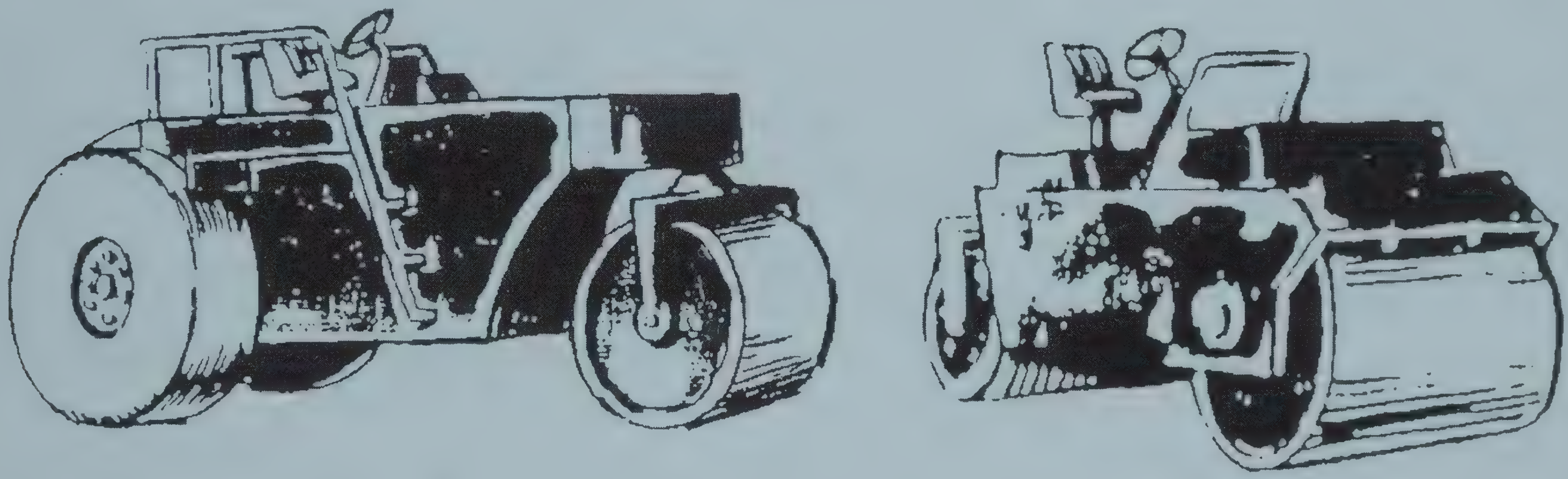
Rolling is a process of densification and if a density resistant to ultimate traffic load is not imparted to the mat at the construction stage, the material will deform under traffic. This will occur principally along the wheel-paths, and consequently there will be formation of channels or ruts on the surface, which may be accompanied by sideways displacement of material this will interfere with the proper drainage of the surface of the carriageway, which is extremely dangerous for traffic, and will lead to rapid deterioration in the pavement structure. Thus, proper compaction is essential.

6.8.2. Factors influencing compaction: the compaction of the mix material is influenced by the type of aggregate, its size, shape (particularly degree of flakiness and elongation), grading, residual moisture content of the aggregate material after drying, the binder content, the viscosity of the binder and the temperature of the mix during compaction. All the former should be taken into account in the asphalt mix design, leaving temperature of compaction as the single most important factor affecting the final result. This must be carefully supervised at the laying site.

6.8.3. Types of rollers: The main types of rollers used for compaction of bituminous courses in highway works are:

(a) The smooth-heeled rollers,
(b) The pneumatic tyred rollers, and
(c) The vibratory rollers

6.8.4. Smooth-wheeled rollers: the smooth-wheeled rollers can be sub-divided into two categories: the conventional three-wheeled rollers (often called a three Point Roller) and the two-wheeled tandem rollers (Fig. 6.16). A recent addition to the range is the tyred roller with a single vibrating steel drum. The two tyred wheels have treaded tyres, and are for driving the roller, rather than for compaction.



(a) A Conventional Three-Wheeled Roller **(a) A Two-Wheeled Tandem Roller**

Fig. 6.16. Smooth Wheeled Rollers

The conventional three-wheeled steel rollers have two large diameter wheels at the rear and one smaller diameter roll at the front but of greater width. The diameter of the drive wheels mounted at the rear may vary from 1.40 to 1.75 m. The front steering roll has smaller diameter and width of about 1.1. m in order to bring about some uniformity in compaction, to an extent. A certain amount of overlap is always provided between the front and rear rolls. Typically, for an 8 to 10 tonne smooth-wheeled roller, the width of the front wheel is about 107 cm while each of the two rear wheels is 45 cm wide, with an overlap of 10 cm. This is the best type of roller on which to fit a cutting wheel, to trim the longitudinal joints in the mat, between passes.

Generally, with a weight distribution of 40-45 per cent on the front wheel and 55-60 per cent on the rear axle, and with less width in the rear wheels, the static load per unit width on the rear drums is about 30 per cent higher than that on the front drum.

Some manufacturers make available three-wheeled rollers with articulated steering and equally large diameter drums in all the three wheels which may gave almost equal load pr unit length on all the drums. It is claimed that the articulated centre-pivot steering enables equal force distribution over the entire the entire roller width and better drum overlap even when turning on a curve or changing lane, etc.

The total weight of the roller generally varies from 4 to 15 tonnes with provision for ballasting in the hollow rolls. The ballast is generally in the form of water but may be sand, concrete blocks or other materials. The load per unit length on the rear drums may vary from 50 to 60 kg/cm without ballast and upto 80 kg/cm with ballast.

Based on experience it is found that for adequate break-down rolling (the first rolling operation after laying) of a bituminous mat, about 58 kg/cm of linear loads is required in the drum which can be achieved by an 8 to 12 tonne smooth-wheeled roller.

Contact pressure is lower at deeper penetration and it increases as compaction increases and the drum rides out of the material to less penetration. Studies have shown that larger diameter drums (with the same load/unit length) may, therefore, produce better compaction in spite of lower compaction pressure than smaller diameter drums at the same penetration.

Rollers with drive arrangements at both the front and the rear wheel drums are also available. The performance of such rollers is claimed to be better because they eliminate the pushing action that occurs with non-powered steel-wheels.

Conventional static tandem rollers generally have drum diameters varying from 1.2 m to 1.5 m and width between1.1. m and 1.4 m.

For selecting the roller drum width, the following formula may be used :

$$W = \frac{M + (n+1)\,p}{2.5\,n}$$

Where W = width of the drum in cm

M = job or mat width in cm

n = number of passes

p = overlap in cm

For the compaction of a 366 cm mat in 3 passes, allowing 15 cm overlap the required width of roller drum is:

$$W = \frac{366 + (3+1)\,15}{3} = 142 \text{ cm or } 1.42 \text{ m}$$

The number of passes required to attain the specified density will be the same as it took to attain the specified density on the test strips.

Two-axle tandem roller may have total weight varying from 2.7 to 13 tones but their static loads per unit length are less than those of three-wheeled rollers of the same total weight. Static tandem rollers of 8 to 12 tonnes total weight have loads per unit length of about 32 kg/cm without ballast and with optional arrangement of ballast, in some makes, the load per unit length goes up to 45 kg/cm.

There are some special three-axle (triple drum) rollers where the axle arrangement is such that when required, the central axle can be made to bear a larger part of the total weight for smoothing out individual high spots. Three-axle rollers may have total weight ranging from 9 to 19 tonnes, the higher range with a ballast arrangement.

Many tandem rollers, especially the lighter ones, are provided with auxiliary pneumatic-tyred wheels for easy and quick movement while in transit between deployments.

Among other useful accessories, a good roller should have an efficient pump-driven sprinkling system to reduce or eliminate pick up of bituminous material sticking to the wheel during compaction. Drums should be equipped with scrapers.

The edges of the drum wheel should be chamfered so as not to leave deep roller marks on the compacted surface.

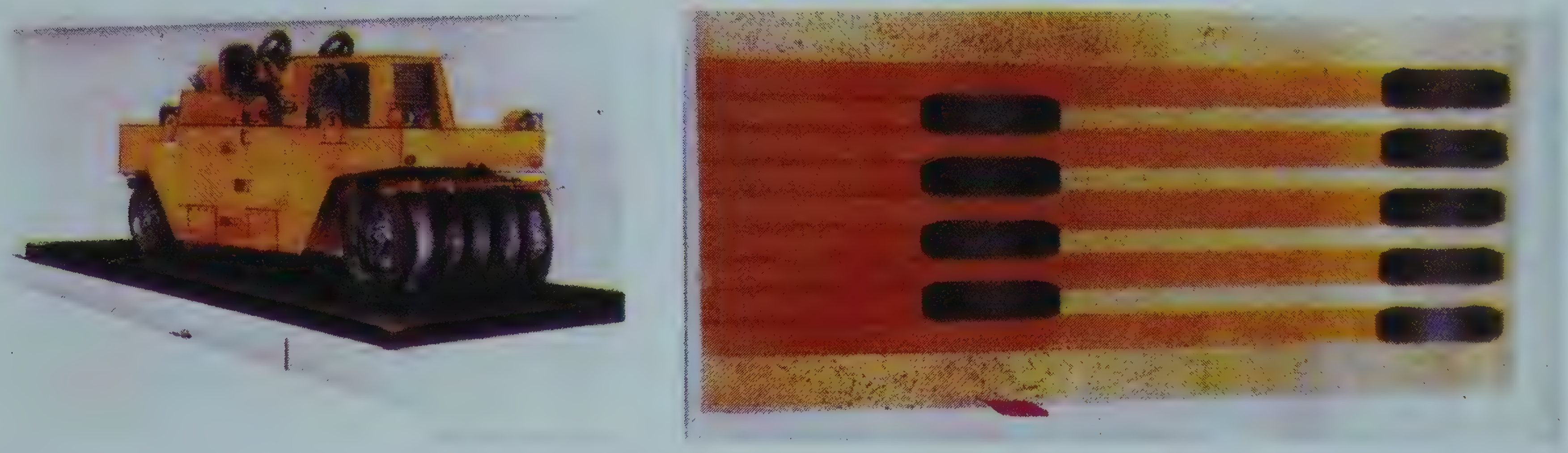
6.8.5. Pneumatic Tyred Rollers (PTR) : The main advantage of a pneumatic tyred roller is that it compacts by "kneading" action rather than 'crushing' action and is able to provide more uniform compaction the Smooth- wheeled rollers; the compaction load is distributed equally on every point of the surface irrespective of the ground profile.

Pneumatic tyred rollers may be of two categories:

(a) Towed pneumatic tyred rollers, and

(b) Self-propelled pneumatic tyred rollers.

In general, for bituminous laying work, only self-propelled pneumatic rollers are used. They may be of single-axle type but generally two-axle types are used. A typical 9 wheeled sell propelled pneumatic tyred roller is shown in Fig 6.17.



(a) (b)

Fig. 6.17. (a) Pneumatic Tyred Roller, (b) Overlapping Wheel Configuration in a Pneumatic Tyred Roller

The tyres must be smooth and those on the same axle must be of epual size and diameter and with uniform tyres inflation not varying by more than 0.35 kg/ sq.cm. Broadly speaking, for bituminous laying work the roller weight , along with ballast when provided, must be able to exert a ground load of about 58 kg/cm width of tread as measured on a have surface. The smooth tyres have square shoulders, and are specially made for the purpose.

The usual makes of rollers have three to seven wheels on the front axle and four to eight wheels on the rear axle. In general, for higher quality bituminous works, compaction by at least seven wheels is prescribed.

The wheels are equally space on the axle and placed in such a manner that those on one axle tread midway between those on the other axle. As in smooth-wheeled rollers, the wheel configuration of pneumatic tyred rollers is also so designed as to provide a certain amount of" in between adjacent wheel paths as shown in Fig. 6.17.

Generally, a large size tyre with greater contact area secures better compaction than a smaller tyre with the same inflation pressure. Tyre pressures are most important, and there is often a facility to control this from the driver's cab.

The roller may vary in total weight from 3 to 30 tones, the higher range being achieved with provision of ballast.

The ballast may be added using different types of loads for example, stone aggregates, iron bars, sand, water, etc. The last two are preferred for ease and quickness in loading and unloading. Sand, specially wet sand, because of larger volumetric weight becomes the first choice because of higher unit weight, if iron of steel is not available.

The weight must be distributed equally on the wheels and for bituminous work for highways, the roller should be capable of exerting a minimum weight of 1200 kg on each wheel. The weight generally ranges upto 3000 kg per wheel for heavy rollers.

There are mainly two types of tyres, one set called standard tyrees and the other set wide-based tyres. Since the transmission of force through the wide based tyres is more vertical than radial, these are preferred by many especially for sealing and finish rolling work The inflation pressure in the standard tyre ranges from 0.3 MPa (3 to 9 kg/cm^2), and the wide based tyre generally works at a pressure of 0.4 MPa ($4kg/cm^2$)

As very heavy tyre pressures may lead to displacement of mix, it is better to get the tyre pressure requirement approved for each job by the project authority.

There are some special makes of pneumatic tyred rollers in which tyre pressures can be varied even during rolling operation.

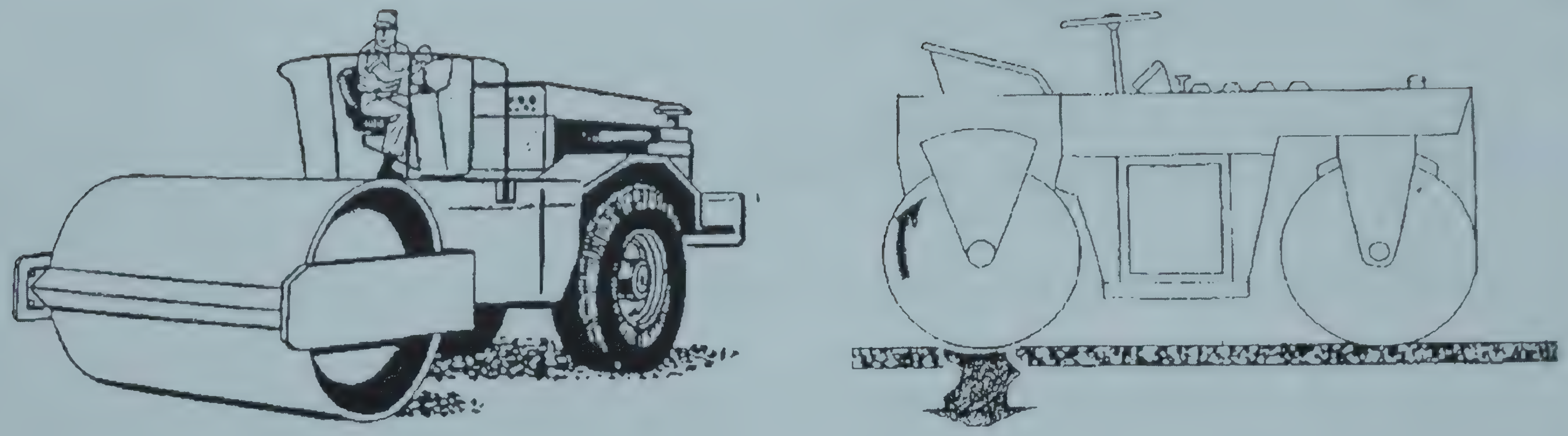
6.8.6. Vibratory rollers

6.8.6.1. General : The usual method of affecting vibration in the compacting drum is with the help of a rotating eccentric mass within the drum which causes and upward as well as a downward acceleration to the drum during each cycle of its rotation. The periodic force generated by the eccentric mass against the drum may be several times larger than the weight of the drum so that the drum tends to be raised free from the ground once during each cycle and then in the next instant slammed down against the ground producing large compactive effort. Thus, a combination of static and dynamic loads overcomes the internal friction in the mix, so as to create improve condition for re-orientation for packing of the particles, thus improving the compaction.

Vibratory rollers are usually are usually made with either one or two smooth steel drums 0.8 to 1.5 m in diameter and 0.9 to 2.7 m in width, They generally have a static weight in the range of 14.to 15.5 tonnes. Single drum vibratory rollers are generally used as combination machines; when equipped with rubber types, they are very useful on steep grades as the rubber tyre provides better traction than a steel drum, Dual steel drum vibratory rollers are generally preferred as they maximise production.

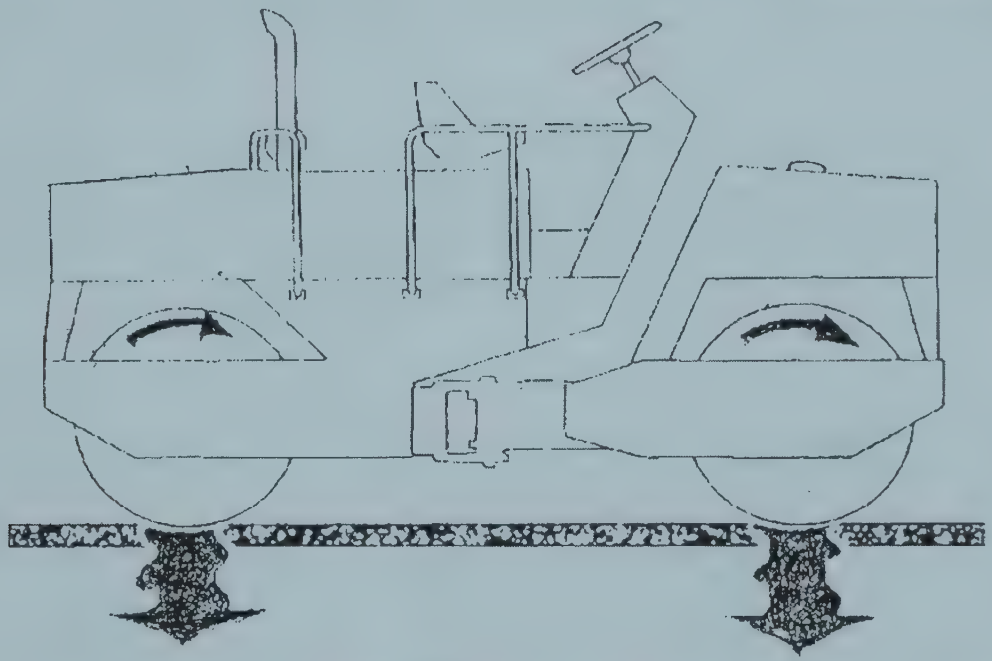
A Light-weight and a Heavy Vibratory Roller are shown in Fig. 6.18.

6.8.6.2. Vibratory parameters: Frequency in any oscillating system is the number of cycles per unit time. Since in the present case there will be one impact per cycle, frequency may be taken as equivalent to the number of



(a) A Single Drum Light Vibratory Roller

(b) A Double Drum Vibratory Roller with ony one of the wheels vibrating



(c) A Double Drum Vibratory Roller with Both Wheels Vibrating

Fig. 6.18. Vibratory Rollers

drum impacts in unit time and may be expressed in Hz (vibrations per second) or VPM (vibrations per minute).

Amplitude being the maximum value of a varying quantity from its mean or base value, in the vibrating system of the roller, it will be half of the total drum movement.

6.8.6.3. Factors of Primary Influence

1. The compactive effort of the vibratory roller is primarily influenced by:-
    (a) the static load/unit length,
    (b) the ratio between frame and drum mass,
    (c) the drum diameter, and
    (d) the vibrating parameters, like, frequency and amplitude
2. Upto a certain limit of weight, increase in static load per unit length leads to direct improvement in compactive effort.
3. The ratio between frame and drum mass influences vibrating parameters. A higher ratio, affected by a heavier frame may improve compaction efficiency up to a certain upper limit beyond which the frame mass may dampen the vibrations, thus, reducing compactive effort and leading to energy wastage.

4. The drum diameter determines the area of contact with the material and its effect is influenced largely by the quality of the mix to be compacted.

5. Studies carried out with variations in frequency and amplitude have shown that operation at frequencies 30-50 Hz (or between 1800 and 3000 vibrations per minute) and an amplitude of the order of 0.3 mm are suitable for compaction of most types and thicknesses of bituminous layers. In general, lower amplitude is applicable to thin layers and higher ones being more suitable for thicker mats and harsh mixes.

6. The resonance of the dynamic force should be adjusted to the foundation and type of material to be compacted.

6.8.6.4. Secondary factors : Needless to say that other secondary factors, like

(i) the number of vibrating drums,
(ii) number of passes, and
(iii) the speed of travel of the roller

Will also influence compactive effort.

Obviously, more vibrating drums and more passes will impart greater compaction and slower speed travel will increase the duration of exposure of the material to the vibrating mass and hence increase compaction.

6.8.6.5. Correct eccentric mass rotation : The distance between successive impact blows by the roll is called impact spacing.

High frequency will result in small impact spacing. This prevents occurrence of ripples and formation of bow-waves in the surface. This also enables higher rolling speed and thus increases output and overall efficiency.

While rolling with a vibratory roller, care has to be taken to ensure that the direction of rotation of the eccentric mass must be in opposite direction to the drum rotation or direction of travel (Fig. 6.19).

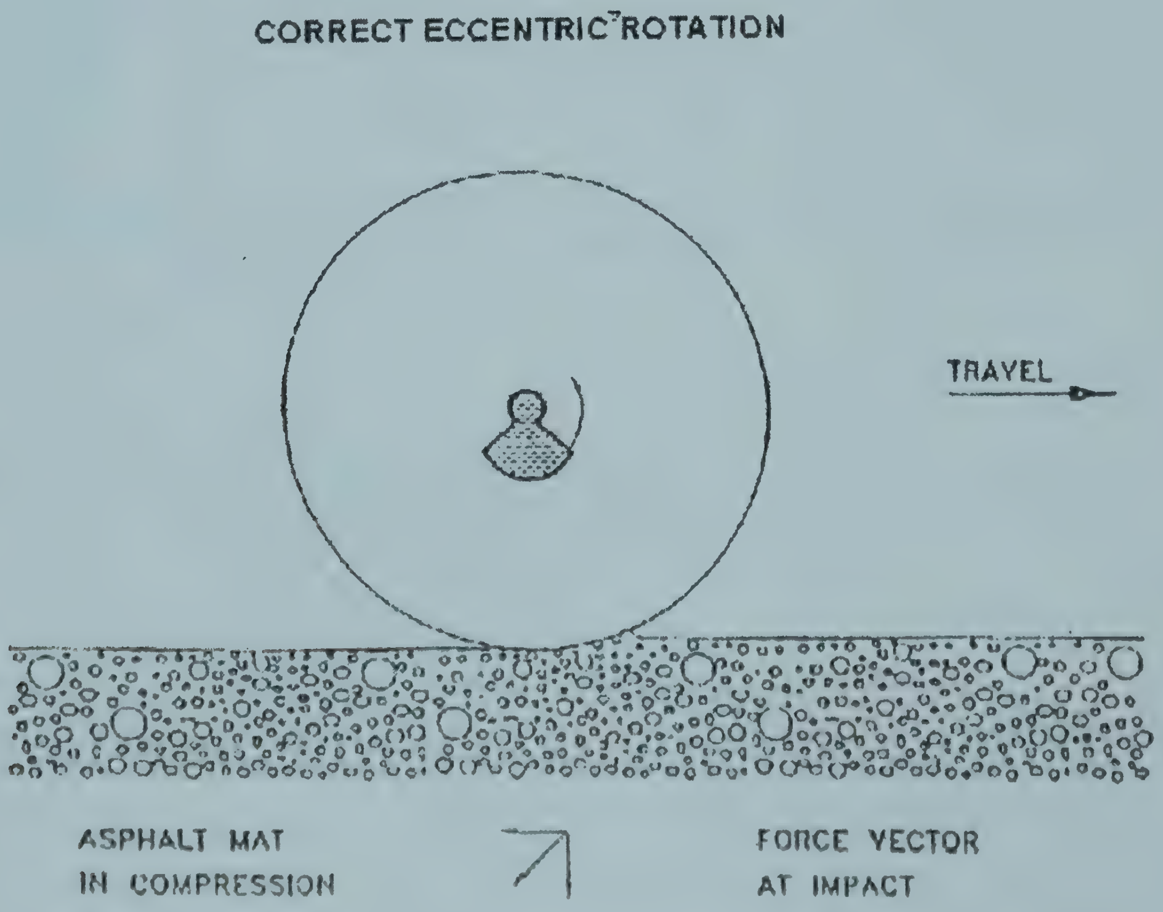


Fig. 6.19. Vibratory Roller Operation (Correct Eccentric Rotation)

If both of these are in the same direction the resultant force of action at impact point of the drum will create tension or a tearing effect on the compacted surface at the back of the drum and a large bow-wave in the front (Fig. 6.20).

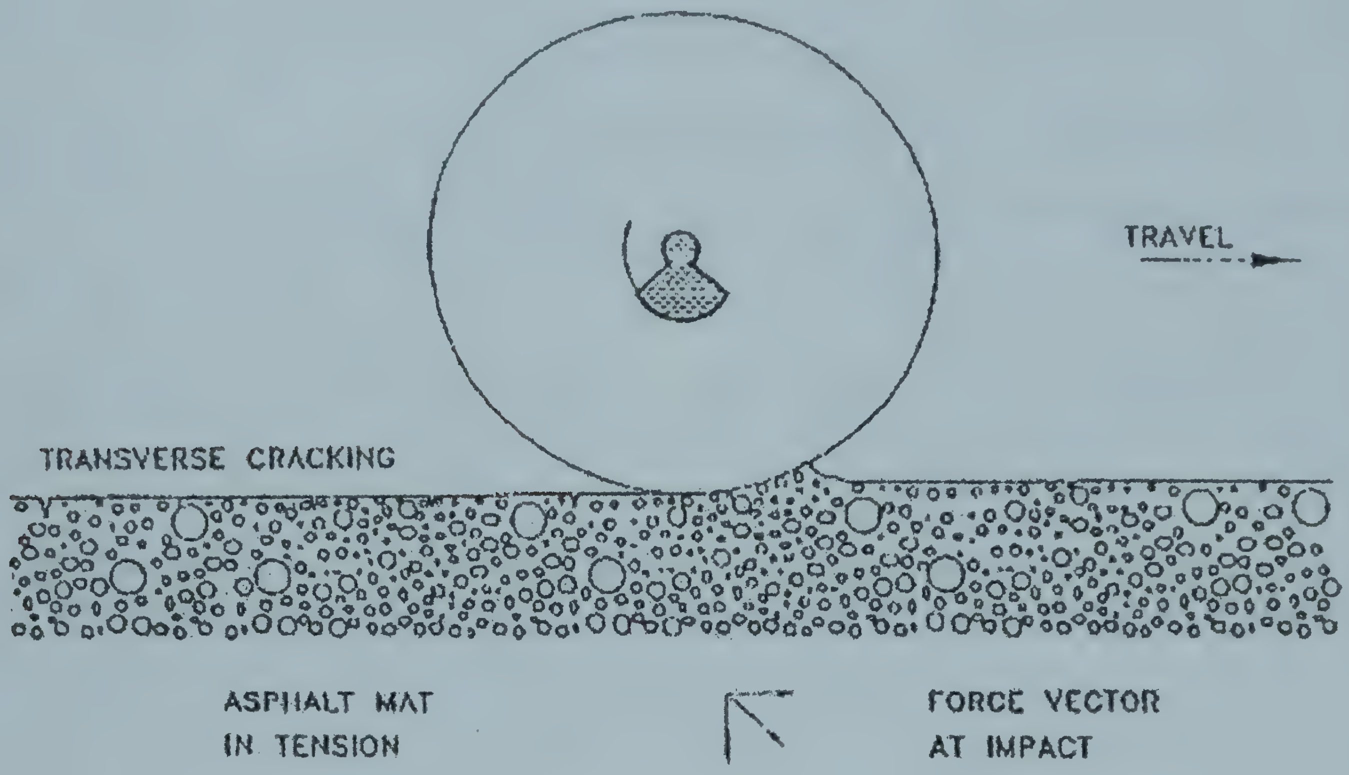


Fig. 6.20. Vibratory Roller Operation (Incorrect Eccentric Rotation)

Opposite eccentric force will result in compression in the mat behind the drum and reduce the wave height on the side of the direction of travel.

6.8.6.6. Combination rollers : Some of the modern types of road rollers are a combination of one vibrating drum and rear axle with three or four pneumatic tyres with a weight range 4-15 tonnes. These road rollers combine the advantages of both pneumatic and vibratory types of road rollers. One such type is shown in Fig. 6.21(a).

6.8.6.7. Hand operated vibratory roller : Where space is restricted, small capacity compactors can be used. A double drum walk behind roller with two vibrating drums and weight range of only 0.4 to 1.0 tonnes is shown in Fig. 6.21 (b).

6.9. Slurry Seal Equipment

The equipment for slurry seal application consists of a self-propelled truck-mounted assembly which simultaneously manufactures and spreads the mix on the job, Fig. 6.22. It consists of the following components:

(1) Aggregate bin

(2) Filler bin

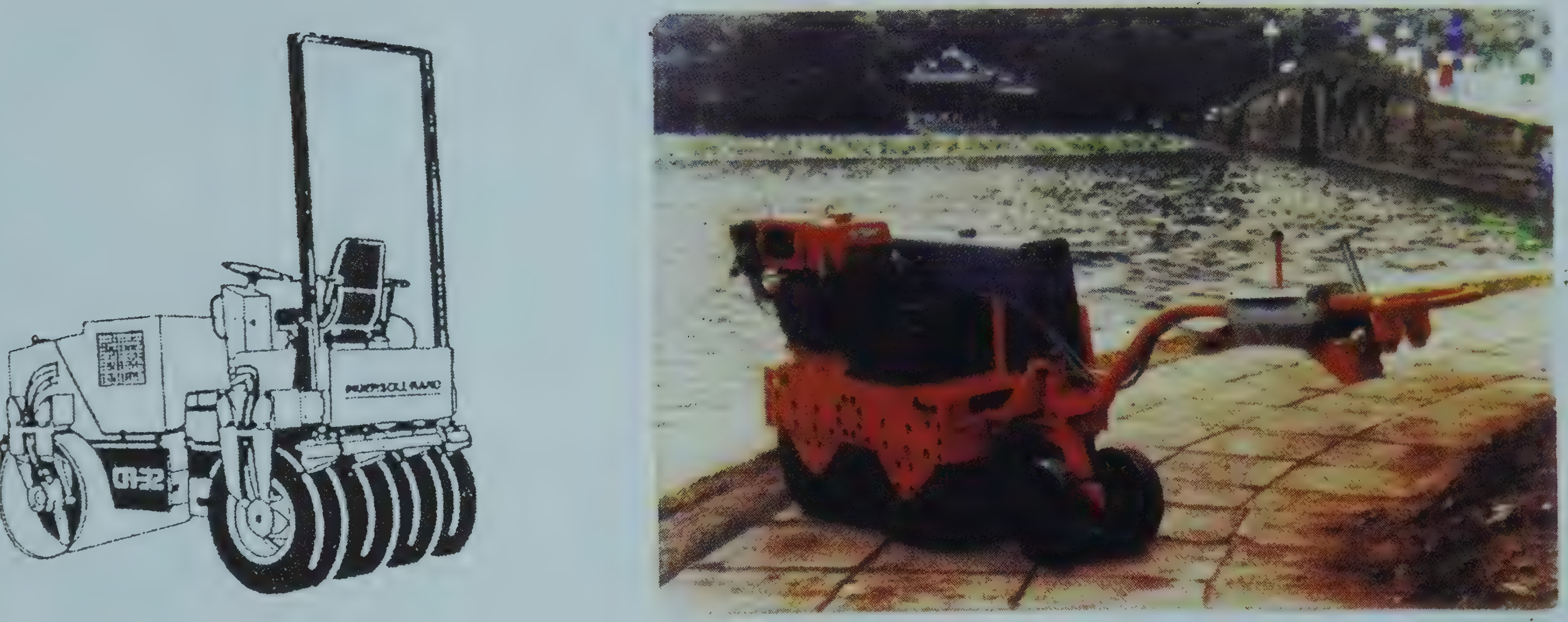
(3) Water and emulsion tanks

(4) Conveyors for feeding aggregates and filler to the mixer box

(5) Pump for emulsion and water

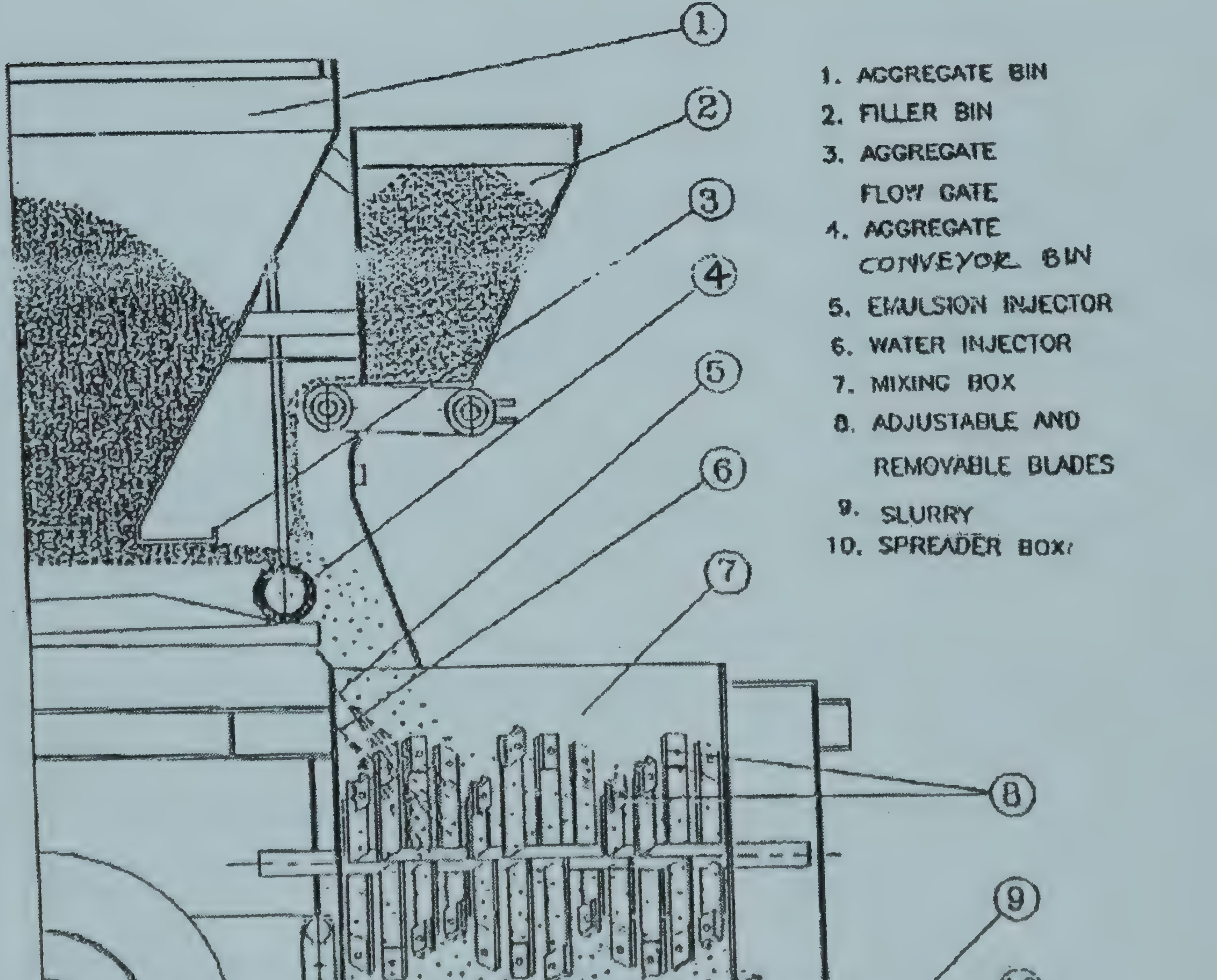
(6) Mixer box

(7) Spreader box to place the mixed slurry on the pavement



(a) (b)

Fig. 6.21. (a) Combination Roller and (b) Hand Operated Vibratory Roller


1
2
3
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5
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7
8
9
10
1. AGGREGATE BIN
2. FILLER BIN
3. AGGREGATE FLOW GATE
4. AGGREGATE CONVEYOR BIN
5. EMULSION INJECTOR
6. WATER INJECTOR
7. MIXING BOX
8. ADJUSTABLE AND REMOVABLE BLADES
9. SLURRY
10. SPREADER BOX

Fig. 6.22. Slurry Seal Machine

The process consists of feeding the aggregates, filler and water into the mixer at the specified rates where homogenisation is achieved. The emulsion is then fed to the mixer and the pre-wetted aggregate is mixed and homogenised with the emulsion to make-up the slurry. The mix is poured into the spreader box, and laid on the road.

6.10. Equipment for Small Scale Works and Maintenance Works

6.10.1. Vibrating plate compactor : The vibrating plate compactor becomes a handy and convenient tool for use in compaction of small and irregularly shaped areas where ordinary rollers cannot access. They are also convenient, light, and very mobile being easy to handle by hand, and therefore a popular tool for all small works, such as pothole patching.

Commonly, the vibrating effect is achieved by installation of a rotating eccentric weight in the system. For small lightweight compactors one eccentric weight is sufficient. For heavier compaction, two eccentric weights are installed, one on either side of the centre of gravity of the compacting plate. The design of the setting of the eccentric weights may be such as to effect slow forward or reverse movement when required. The plate will be smooth and rounded at the edges so as not to leave edge marks or imprints when working on bituminous surfaces.

The plate compactor is normally provided with a long steel handle so that the operator can walk behind it and control the operation.

A typical vibrating plate compactor is shown in Fig. 6.23 (a).

For working in very tight and inaccessible areas, vibratory plate compactors can be equipped with a remote control arrangement.

6.10.2. Impact plates or impact tampers : For effective compaction in small and narrow trenches or other confined areas, impact plates may also be used. Impact plates or impact tampers, as they are called, utilise the kinetic energy of a load falling from a height to impart larger compactive force on comparatively small area. The impact plate is also provided with holding arrangement for hand operation.

An Impact Tamper is shown in Fig. 6.23 (b).

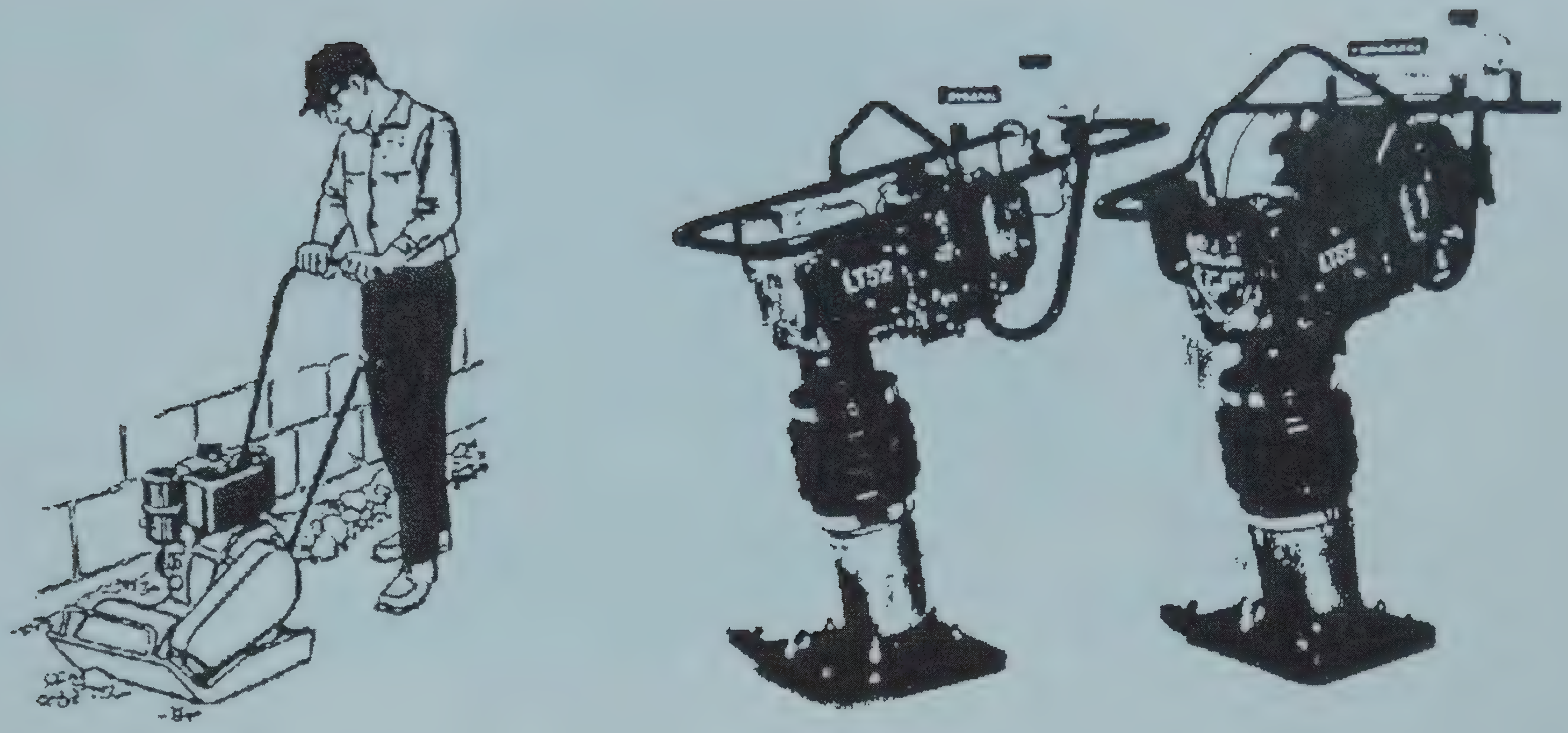
6.10.3. The ripper : The ripper is commonly used for rock recovery or removal. In bituminous surfacing works, it becomes a handy tool for removal of an existing bituminous surface prior to its crushing and use in re-cycled mixes.

The advantage of use of rippers is that it can economically remove a full-depth layer in one operation.

Its disadvantages are that unlike milling, after ripping the material, chunks have to be subjected to crushing which takes additional time and there is always the chance of contamination due to mix up with underlying granular layers. Also, a ripping operation requires complete closure of traffic and therefore, rippers are more suitable for use on unimportant roads with low traffic volume.

Apart from the need for strong high-tensile steel ripper shanks with replaceable points, the equipment also requires a heavy and powerful tractor to be able to give an adequately strong traction to the teeth for working.

There are a few standard methods of working the ripper with appropriately shaped ripping tools such as, a radial arc type tool and parallel linkage type tool, etc.



(a) Vibrating Plate Compactor **(b) Impact Tampers**

Fig. 6.23. Vibrating Plate Compactor and Impact Tampers

6.10.4. Cold-planing (milling) : For pavement removal work, cold-planing or milling is an effective alternative to ripping and crushing. The equipment consists of a cutting drum equipped with a series of tungsten-carbide tipped teeth, mounted on a wheeled or tracked vehicle fitted with an elevator arrangement for moving the milled material onto the transportation trucks. Milling can be carried out in atmospheric temperature but is most suitable during the hot part of the day (noontime and early afternoon) and is also especially applicable during the summer months of the year.

The cost of a milling operation depends upon various factors especially, on the age and the hardness of the pavement to be worked, (on which the tooth wear and consequent replacement cost depends) and the ambient temperature at the time of the operation.

Compared to the ripping and crushing, milling presents several advantages such as:

(1) Immediately, after the milling work is completed the road can be used by traffic pending further stages in the operation of the project,

(2) It can be employed for pavement profiling and surface texture improvement even when recycling is not involved,

(3) It is environmentally more friendly and does not produce any fumes or heat,

(4) Partial reclamation is possible,

(5) Separate crushing requirement is eliminated and this also results in high overall productivity.

Modern cold-planing machines have adjustable widths generally upto 4 metres or so and are able to recover larger depths of material (relative to hot-planing) and can take off as much as 30 mm or so in one pass. A modern cold-planing machine is shown in Fig. 6.24.

The control panel provides automatic grade and slope-setting and depth adjustment (upto ±3 mm accuracy).

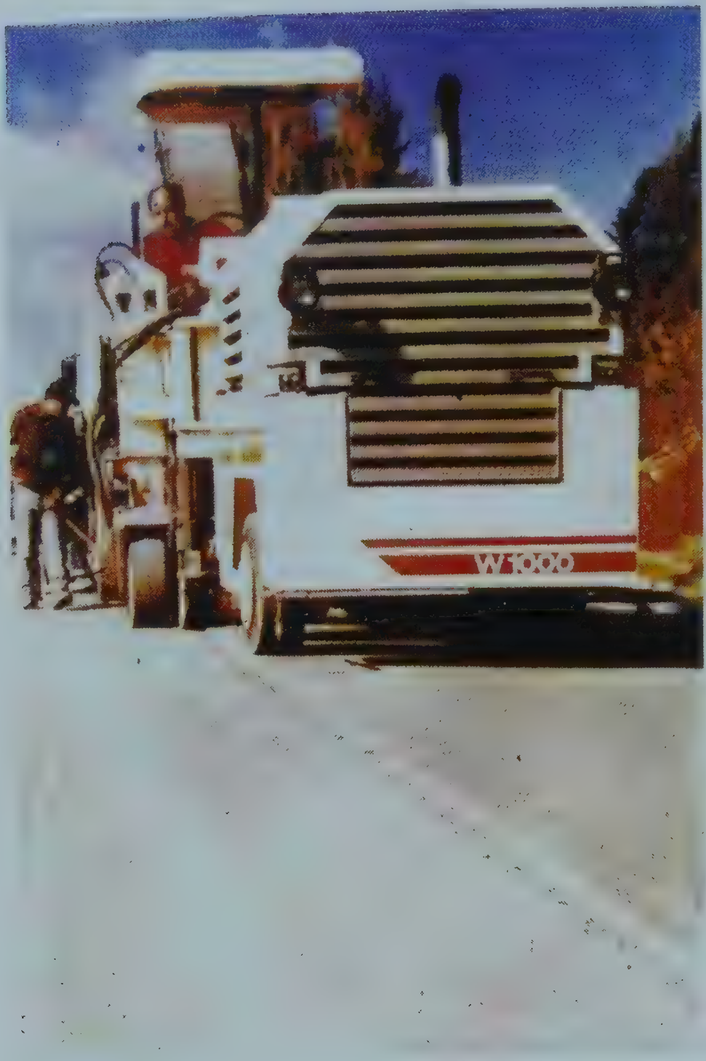


Fig. 6.24. A Cold-Planing Machine

6.10.5. Hot-planing : Compared to cold-planing, the depth of recovery involved in hot-planing similar, but is usually limited to between 40 mm and 50 mm or so.

The equipment is a combination of two separate units-one being the heater or burner unit and the other is the cutting drum. The heater may consist of infra-red panels to heat and soften the material on which the cutting drum works but more often an oil or gas flame heater is used.

6.10.6. Bitumen boilers : Bitumen boilers are available in 100-1000 litre capacity range. These are portable and very useful for small jobs and maintenance works. They are fired by coal, wood, oil or gas. A conventional design of a bitumen boiler is shown in Fig. 6.25.

6.10.7. Arrangement for lifting bitumen drums : When bitumen is supplied in drums, it becomes necessary to lift the drums to the inlet of the bitumen boilers. A chain-pulley system of lifting is common. Such a system is shown in Fig. 6.26.

6.10.8. Bitumen hand spraying equipment : For small works, spraying of bitumen by hand becomes unavoidable. This can be done by a system wherein a pump is attached to the boiler unit itself. The pump can be operated by hand or mechanically. From the pump, a flexible hose with a spray lance attached. The rate of application of the binder can be adjusted by varying the height of the nozzle above the ground. The angle of 45° for spraying is of assistance to the operator in obtaining uniform rate of cover.

6.10.9. Hand-operated drum mixer : For small premix jobs, hand operated drum mixers are employed. The mixer can be improvised from a bitumen drum or can be specially fabricated. A hand operated drum mixer is shown in Fig. 6.27.

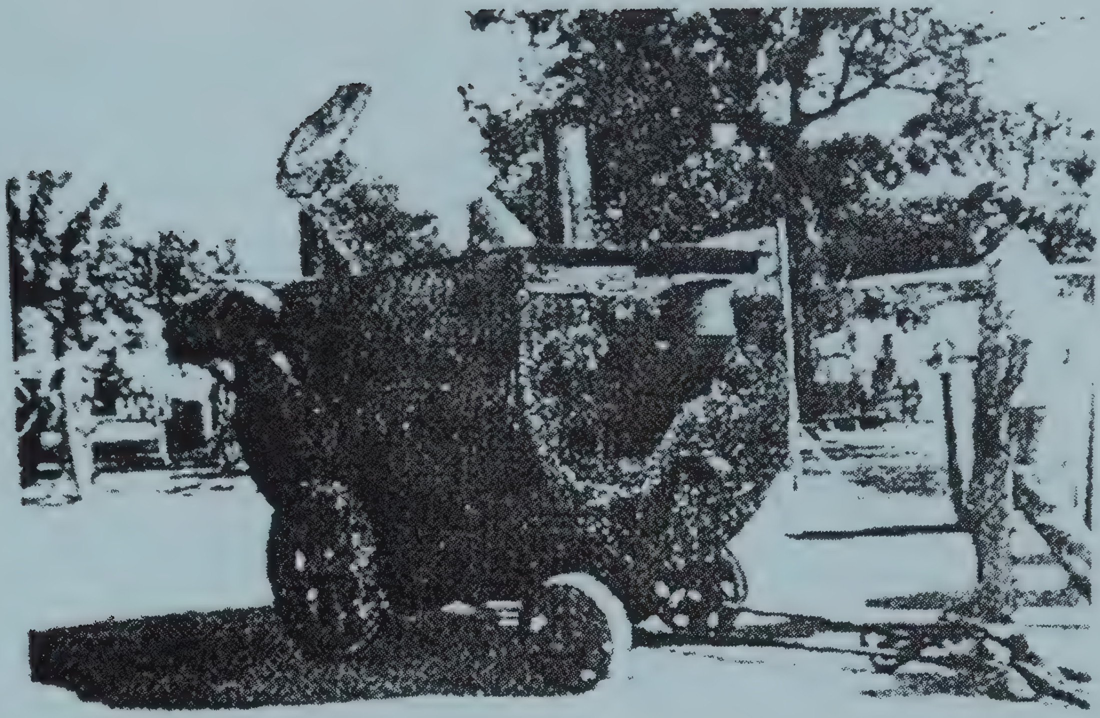


Fig. 6.25. A Conventional Design of a Bitumen Boiler

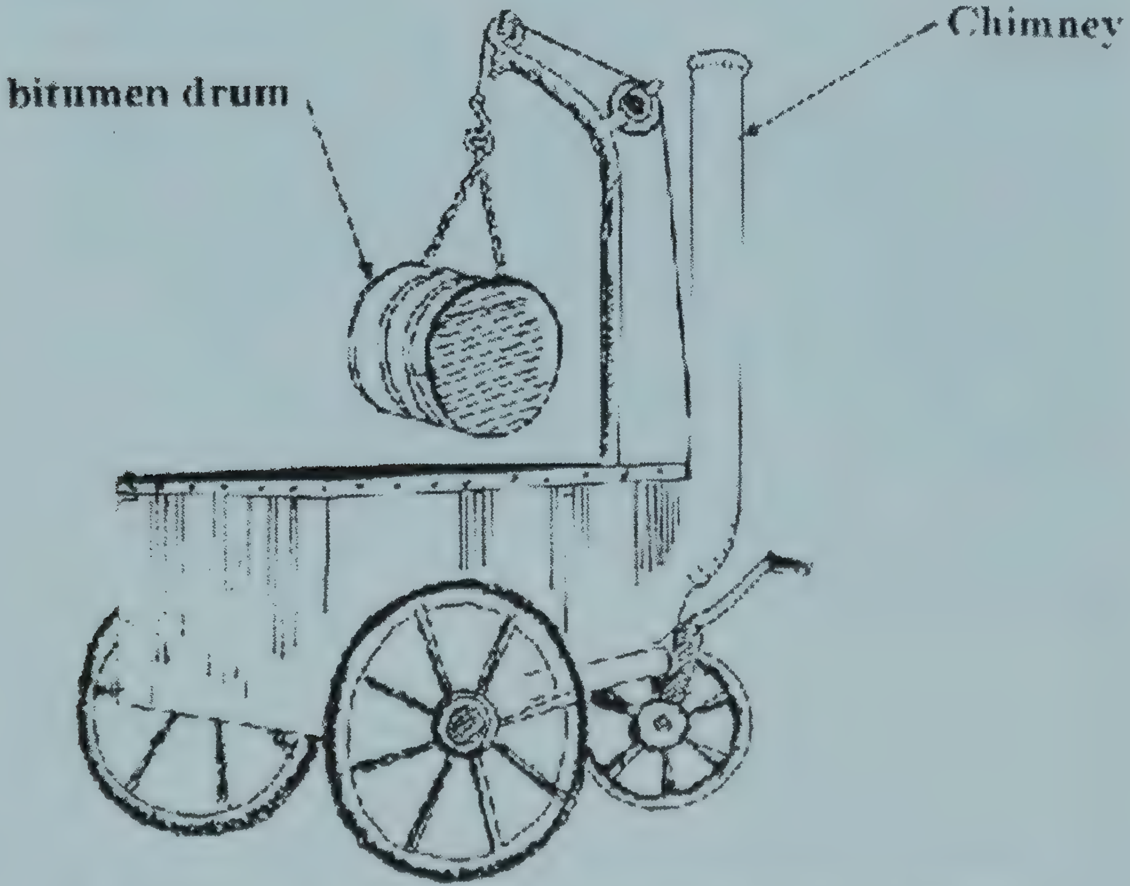


Fig. 6.26. An Arrangement for Lifting Bitumen Drums

6.10.10. Small asphalt cold-mix plants : For maintenance works, small cold-mix asphalt plants in the range of range of 3-5 tonnes/hr. can be used. The plant consists of an aggregate feeder, a mixing unit, optional bitumen heating unit and a storage unit (Fig. 6.28).

6.10.11. Small capacity hot mix plants : For repair works and small jobs, small capacity hot mix plants become very useful. The normal capacity is in the range of 3-5 tonnes/hr. or 6-10 tonnes/hr. The plants have an

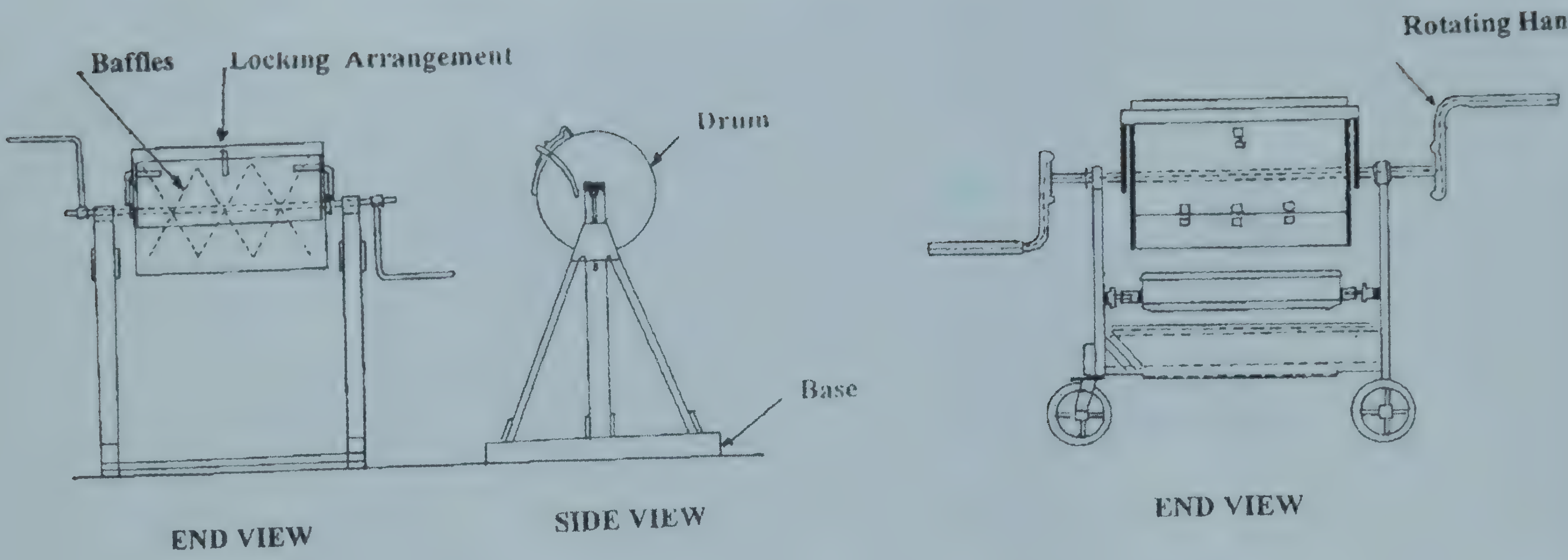


Fig. 6.27. Hand-Operated Drum Mixer

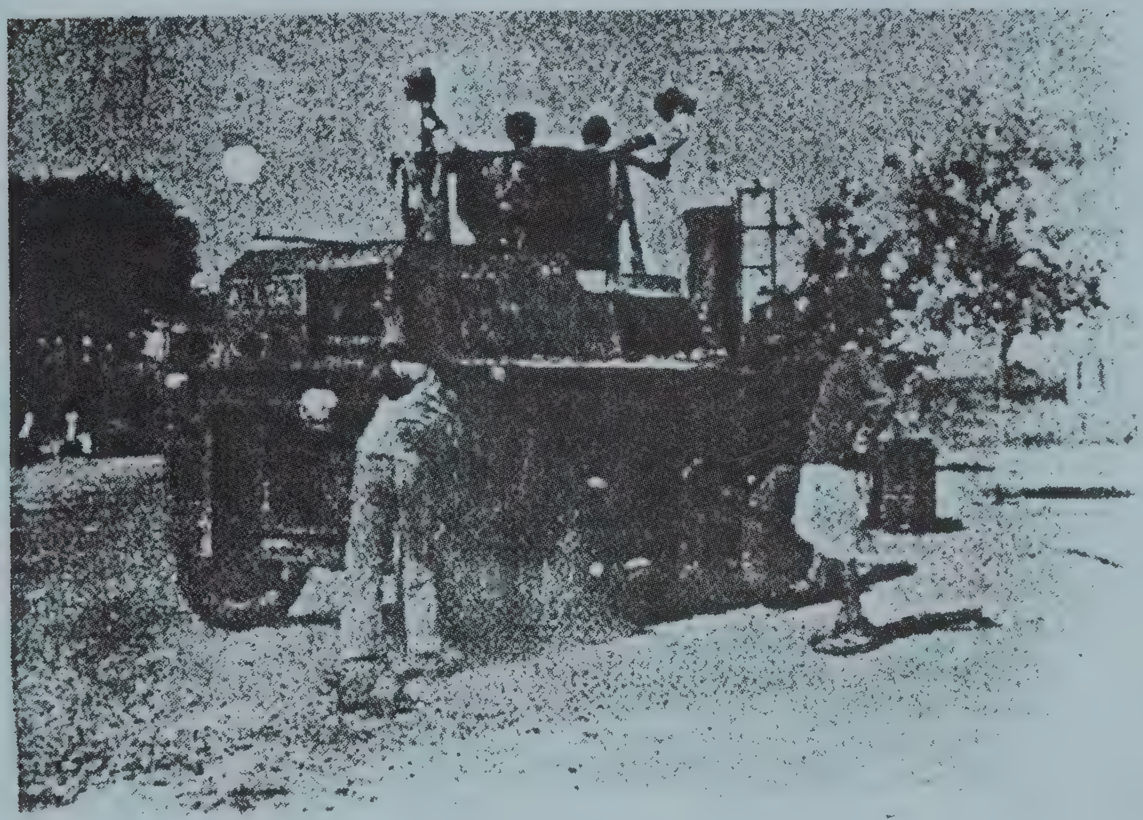


Fig. 6.28. Cold Mixing Plant

arrangement for heating the aggregates either in a separate dryer unit or in the mixing drum itself. Plants with burners in the mixing drum are also available. A small capacity hot mix plant is shown in Fig. 6.29.

6.10.12. Camber board : Portable camber boards are needed for checking the cross-profile where laying is done manually. Two designs are given in Figs. 6.30 (a) & 6.30 (b).

6.10.13. Pothole repair machines : In India, pothole repair has been carried out, until recently, only by manual methods. In developed countries and even in developing countries, however, the use of pothole repair machines has been common in the past for a long time. The use of a pothole repair machine not only provides a good quality repair, that lasts much longer than manually filled potholes, but also the process is very fast. There is a good control on the quality of bituminous materials used for filling up potholes and it is-common to effectively repair 3

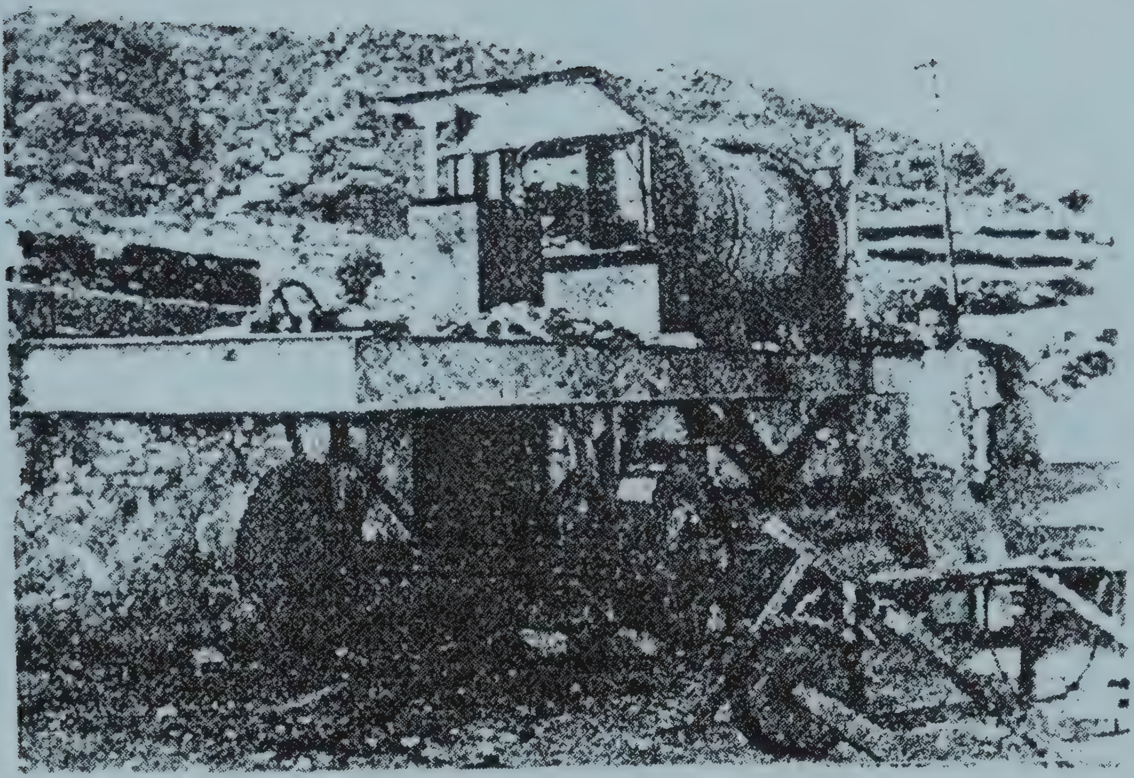
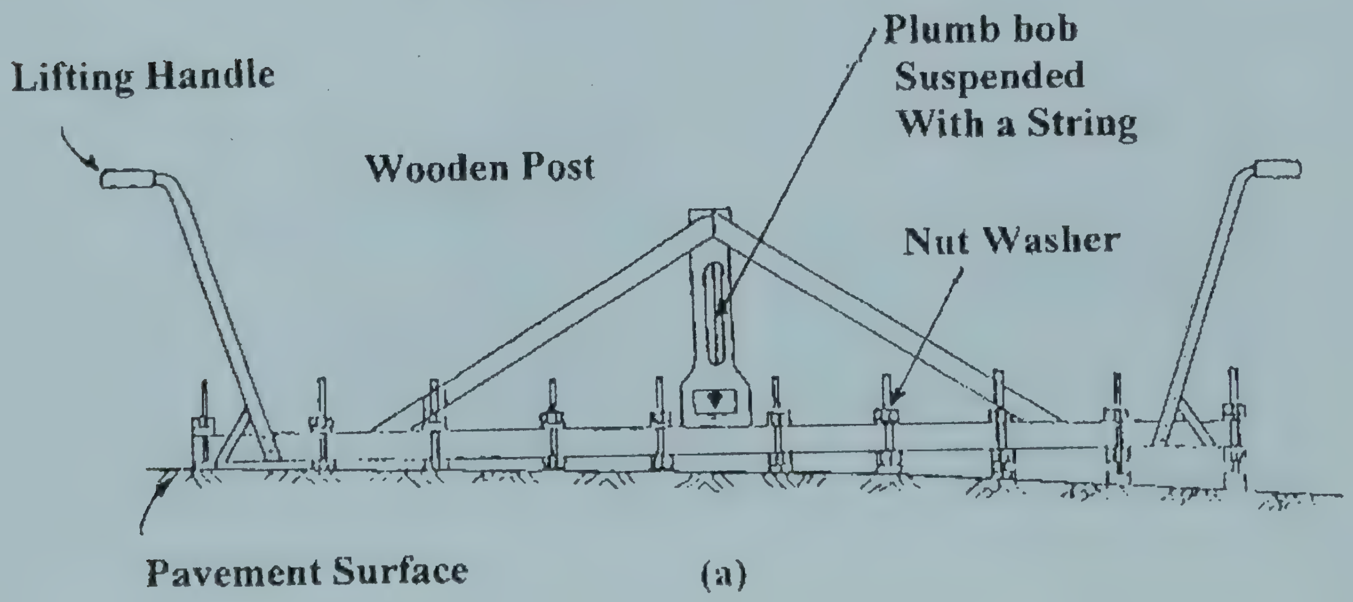
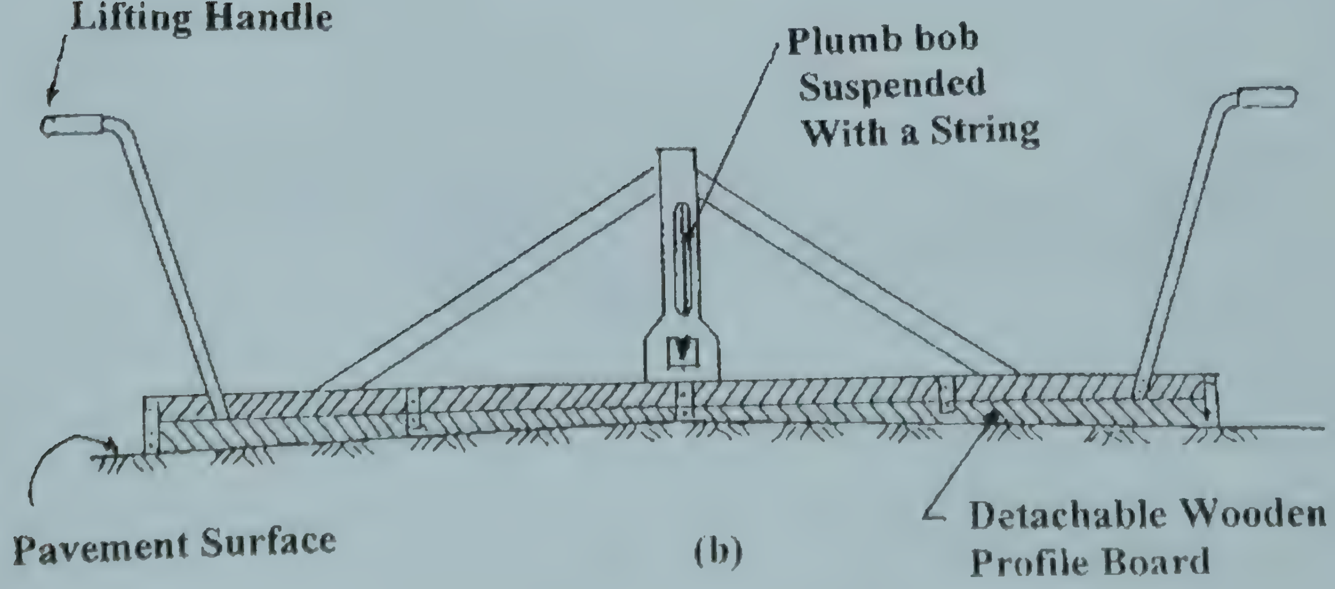


Fig. 6.29. Mini Hot-Mix Mixing Plant



Lifting Handle
Wooden Post
Plumb bob
Suspended
With a String
Nut Washer
Pavement Surface
(a)



Lifting Handle
Plumb bob
Suspended
With a String
Pavement Surface
(b)
Detachable Wooden
Profile Board

Fig. 630. Two Designs of Camber Board

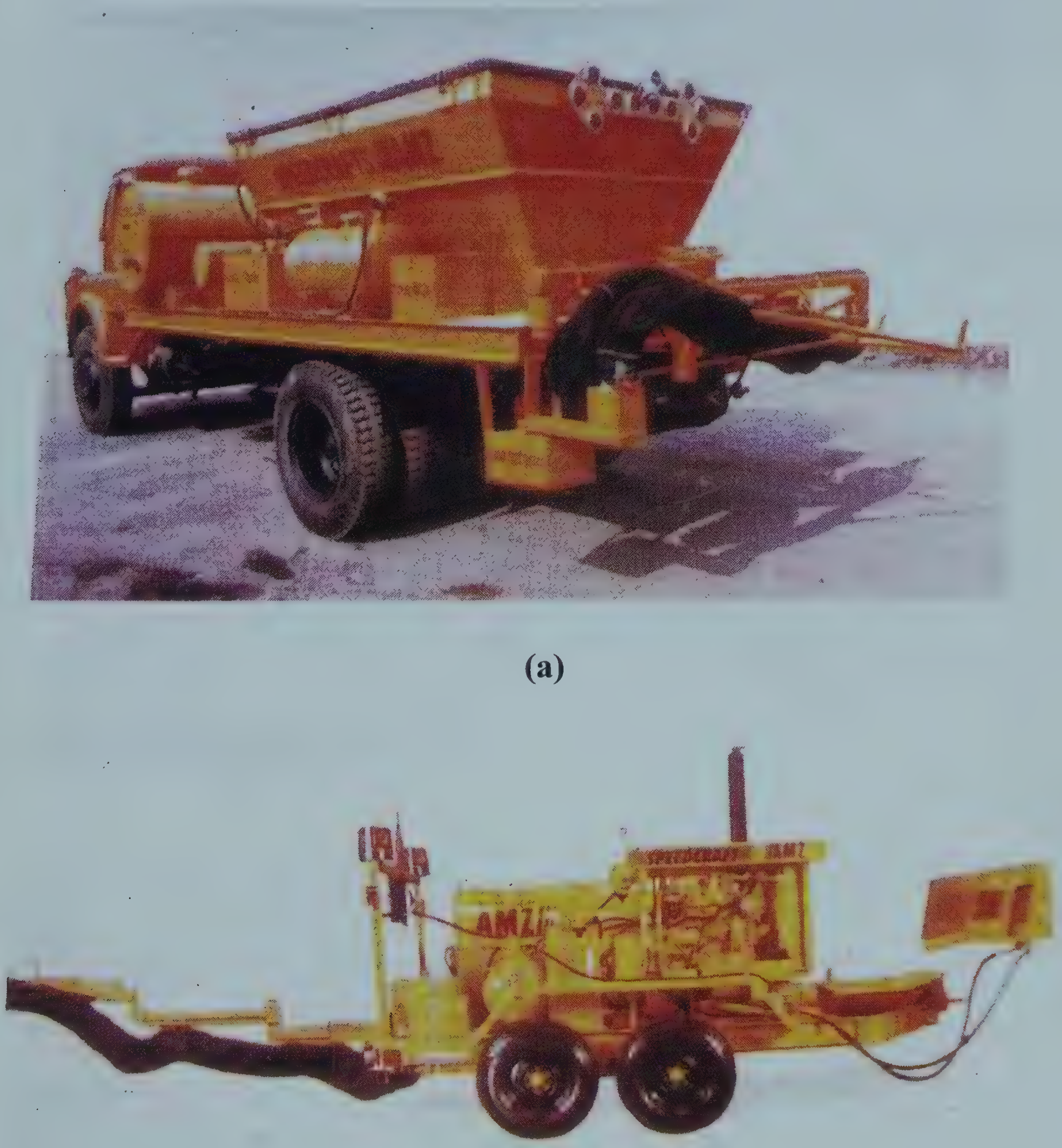
to 4 km of a badly potholed road per day. The potholes filled up by a machine can easily last for a period of about 5 years or longer, depending upon the traffic and climatic conditions. With long distances of badly potholed roads in India, the use of pothole repair machines holds considerable potential for the future.

Broadly, there are two types of pothole repair machines.

(i) using cold mix bituminous material for filling up the pothole

(ii) using hot mix bituminous material for filling up the pothole

In India, the pothole repair machines being manufactured are basically designed for use of cold mix bituminous material for filling up the pothole. Fig. 6.31(a) shows a truck mounted design about 8.5 m long 2.4 m wide while Fig. 6.31(b) shows a trailer machine with 4.36 m long, 2.35 m wide trailer, each machine



(a)

(b)

Fig. 6.31. (a) & (b). Two Indian Designs of Pothole Repair Machine using Cold Bituminous Mix

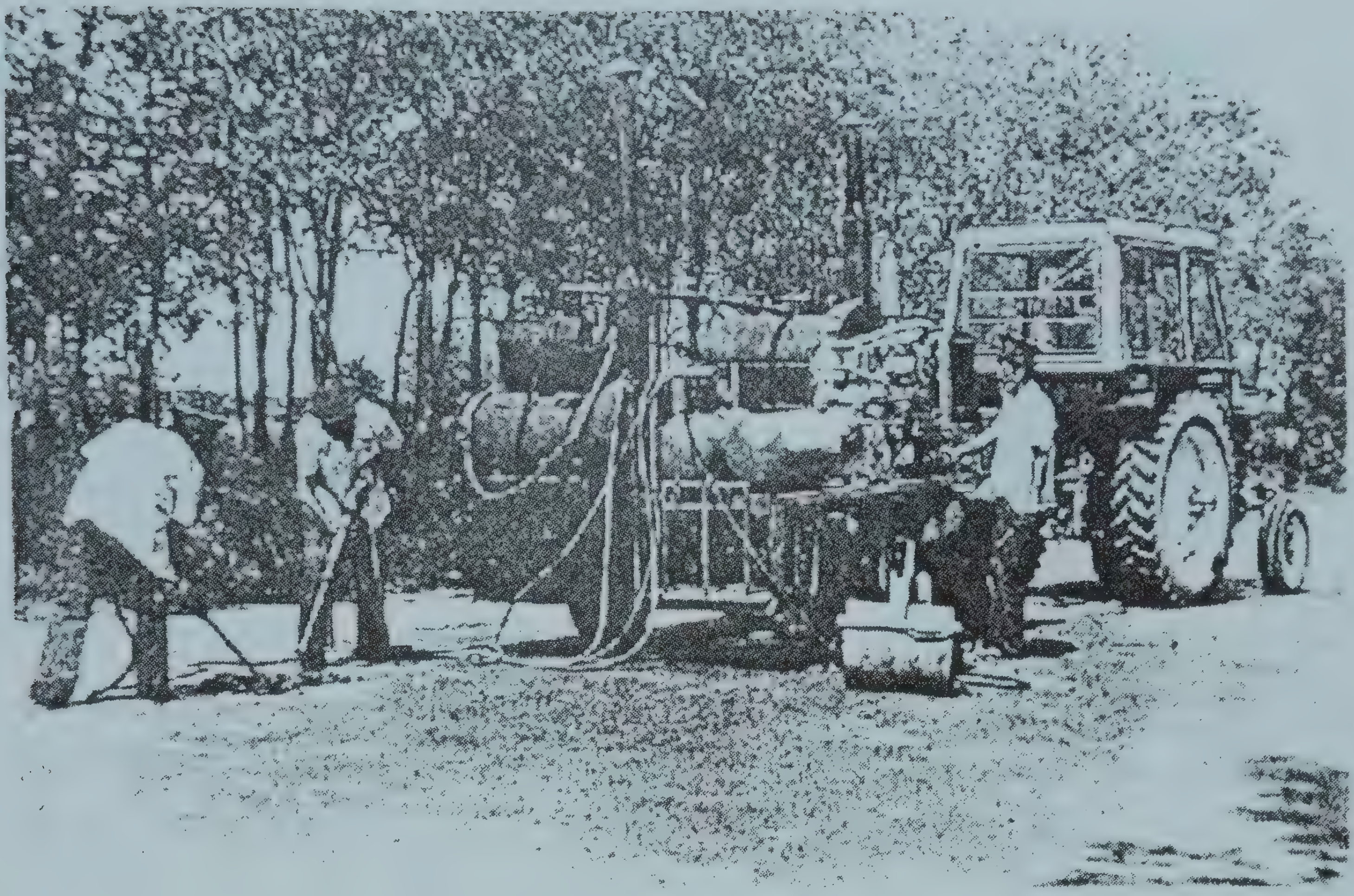


Fig. 6.32. A Pothole Repair Machine using Hot Bituminous Mix for filling the Potholes

having an asphalt tank of 950 litre capacity. Using these machines, the first step is to clean the working surface by a blower, delivering up to 15.5 m^3 of air per minute at 320 km per hour for thorough cleaning. After thorough cleaning, opening a valve injects asphalt emulsion at high pressure for spraying a thin tack coat. After the application of tack coat, operating a switch activates the displacement stone feeding system. The aggregate is fully coated with emulsion as it passes through an internal high-pressure spray ring inside the nozzle. Adjusting the ball valve on the nozzle controls the amount of emulsion; normally it is opened halfway during the filling process, which gives 5 per cent bitumen content. The pothole filling is injected at a high speed, 115 kph by virtue of which compaction is achieved automatically.

Fig. 6.32 shows a design using hot mix bituminous material for filling up potholes, where bitumen and aggregates are heated separately, mixed, laid and compacted by a small Cylindrical vibratory roller. This design was developed in China and was considered suitable for developing countries in the ESCAP region. This is a tractor towed road maintenance machine, drawn by a 28 horse power tractor Which has two rows of seats for road maintenance crew. It is suitable for heating and mixing bitumen with aggregates (mixing capacity 0.06 cu.m, approximately 100 kg), pneumatic road grooving (grooving efficiency 8.2 m^2/hr. depth of groove 3.5 cm) and removing dust by blower (air pressure : 5 kg/cm2). It can cover a length of about 3 km per day of a badly potholed road.

6.10.14. Emulsion sprayers : With the increasing popularity of using bituminous emulsions as a binder, mostly for maintenance work, a number of small capacity designs of emulsion sprayers have emerged. Two such designs (225 litre and 65 litre tank capacities) are shown in Figs. 6.33 (a) and (b). The pressurised vessels are designed to spray emulsion at 5 to 6 kg/cm^2 working pressure. The spray lance is 16 aim dia brass tube and five brass nozzles are provided. Discharge pipe is about 10 m long. These sprayers can be used for prime coat, tack coat, seal coat or fog sealing choosing the design appropriate to the magnitude of the work. In the bigger model, a second pipe attached to the compressor helps blowing away dust for cleaning the surface under repair. Another simple design utilising an empty oil drum is shown in Fig. 6.33 (c). With a weight of only about 56 kg, it can be placed on a small truck

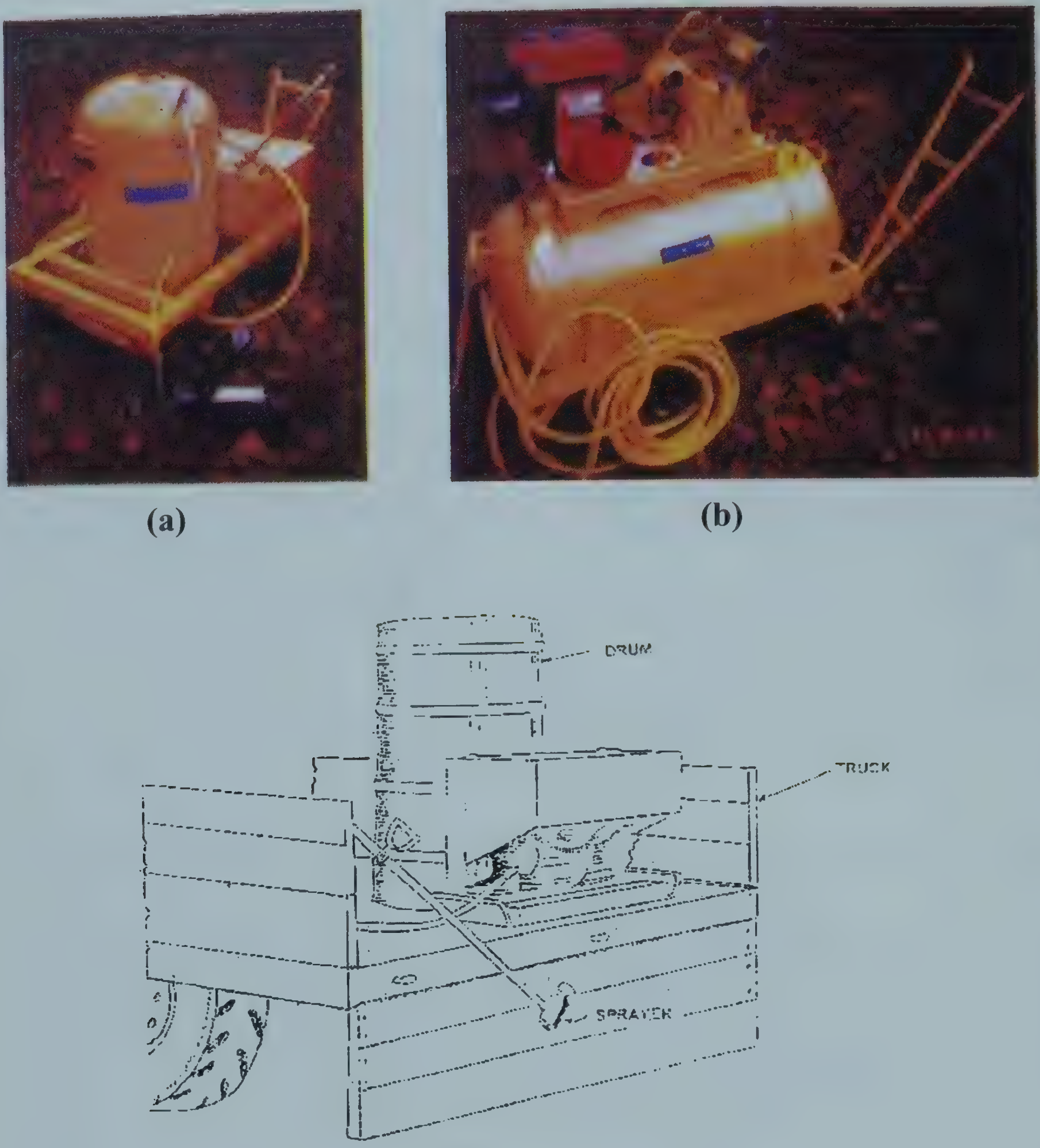


Fig. 6.33. Three Designs of Emulsion Sprayer

and can spray emulsion as well as pour off liquids at a nominal rate of 20 litres per minute with the engine running at 900 rpm.

6.10.15. Mechanical brooms : Before undertaking any surface treatment or the construction of new surface course on an old pavement, it is necessary that the existing surface and cracks be thoroughly cleaned. Such cleaning brooms can vary from small towed revolving cylindrical drum brooms to elaborat self-propelled combination brooms with vacuum and magnetic debris filters. Areas not accessible to power equipment should be swept with hand brooms. Steel, fibre and plastic are used for bristles in the powe brooms.

One simple design of tractor towed road sweeper is shown in Fig. 6.34. The sweeper is designed fo use with almost any tractor, which is fitted with hydraulic lift, three point linkage and power take-off. The brush sections (about 0.5 m diameter, 2.1 m in length) can be in crimped steel wire or poly-propylene and are easily replaceable. The sweeping width is 2.1 m and these sweepers can be supplied with sweeper collector attachments; water tank and sprinkler attachments. Different lengths can be provided depending on actual requirements.

For areas inaccessible to power brooms, manual methods of cleaning can be adopted by using wire brush or bristle brush as shown in Fig. 6.35 (a) and (b).

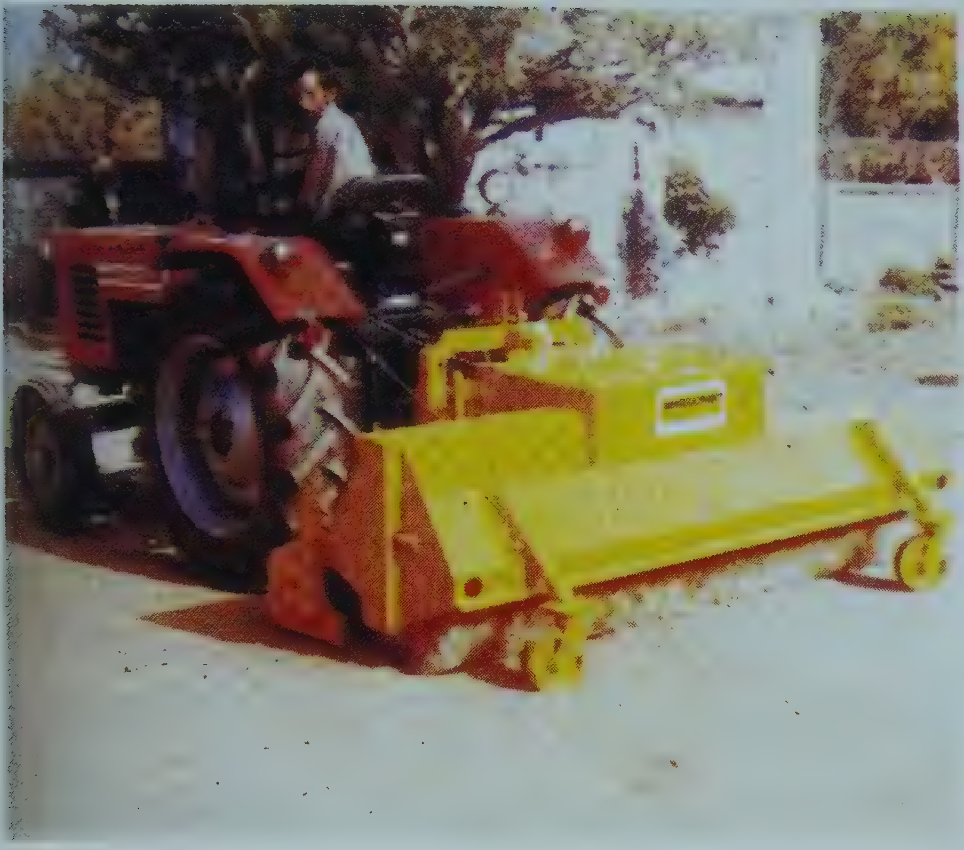


Fig. 6.34 Mechanical Broom

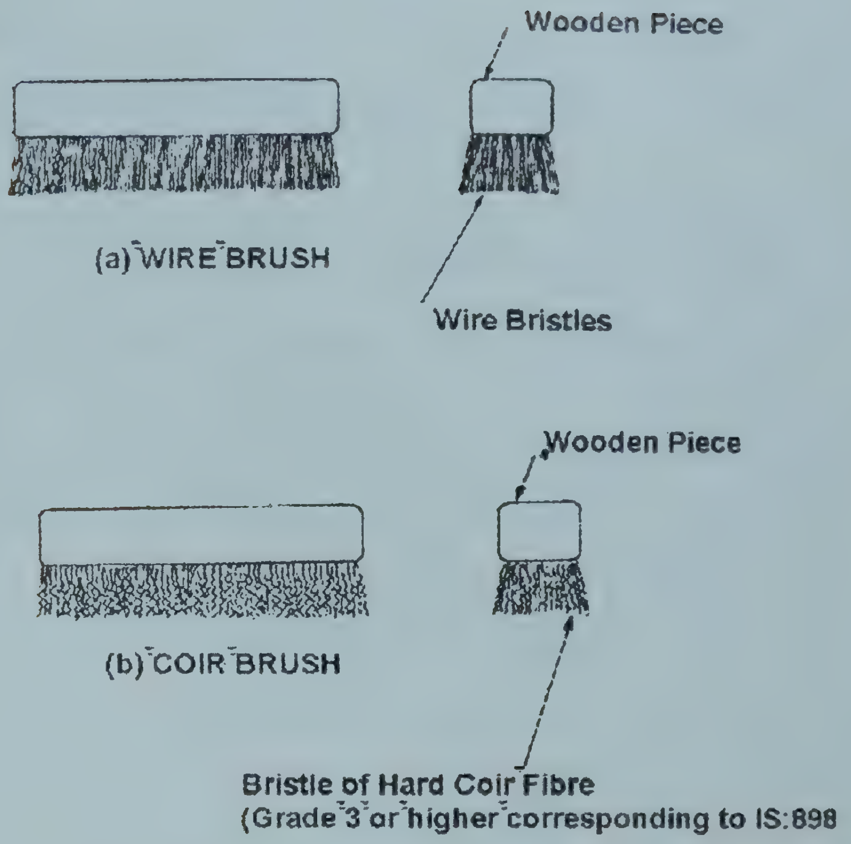

Wooden Piece
(a) WIRE BRUSH
Wire Bristles
Wooden Piece
(b) COIR BRUSH
Bristle of Hard Coir Fibre
(Grade 3 or higher corresponding to IS:898

Fig. 6.35 (a). Wire Brush (b) Coir Brush

6.10.16. Kerb laying machine : Until recently, kerb laying has been carried out by manual methods,. using pre-cast cement concrete kerb sections. However, use of a kerb laying machine not only, enhances the quality, but also offers a very fast procedure of kerb laying. A kerb laying machine is shown in Fig 6.36. The desired grade of cement concrete mix at the required consistency is fed into the machine and with proper adjustments of shape, the machine lays the kerb as shown in Fig 6.36

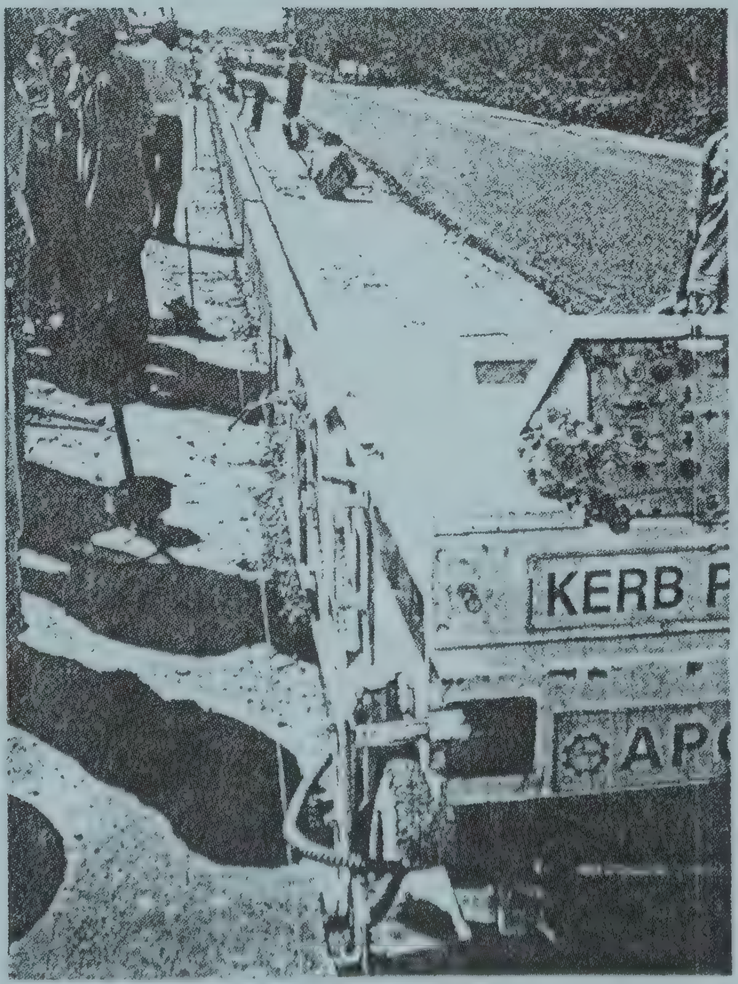


Fig. 6.36. A Kerb Laying Machine

CHAPTER 7

MIX DESIGN OF DENSE-GRADED BITUMINOUS MIXTURES

7.1. Introduction

In the early period of bituminous work, it was a common practice to adopt "recipe" mixes. The unprecedented rise in traffic volume and vehicle weight in the recent years has underlined the need to produce dense and impermeable mixes. There are many desirable properties which modern bituminous mixes should have, which can only be achieved if careful thought is given to the selection of materials and their blending. This is the objective of mix design. Mix design is a pre-requisite in all modern "non recipe' type specifications for dense-graded bituminous mixtures.

7.2. Desirable Properties of Mixes

For good bituminous mixes the following properties are desirable:

- High stability, which is the ability to resist permanent deformations
- Good durability and long life, including resistance to abrasion by traffic
- Good elastic properties
- Good resistance to fatigue
- Low permeability to water and air
- Good workability when hot

In addition, when used to form road surfacings :

- Good skid resistance
- Good riding quality
- Acceptable level of noise under traffic

Also, pavements made with these mixes must be :

- Economical, not only in their initial cost, but also in terms of their maintenance needs during their design life.

A good mix design strives to produce a material that has most of the above properties at an economical cost.

A careful selection of the type of aggregates, their shape and grading, the type and quantity of binder and the degree of compaction of the mix are necessary in order to obtain high stability. Stability is produced by internal friction between the aggregate particles and the cohesion supplied by the binder. For a given grading of aggregates and compactive effort, the stability of a mix is at its peak at a particular binder content. A binder content lower than the optimum presents difficulties in compaction, whereas, at a higher binder content the bitumen reduces the inter-particle contact.

Durability is achieved by incorporating hard and tough aggregates, which can withstand the dynamic loading and the abrasion caused by traffic, by the selection of the correct binder type and amount in the mix and by good compaction. Provided there are sufficient air voids in a mix, high binder content helps in achieving long life. Low binder content results in a thin film coating the aggregate particles and high air voids, both of which increase the rate of oxidation of the bitumen. A thicker film delays the oxidation process. The volatiles in a binder evaporate during the life of the pavement. There need to be sufficient volatiles in the binder to keep it elastic. It, therefore, follows that the amount and type of binder and its viscosity must be carefully selected.

The elastic property of a mix imparts flexibility to the pavement layer, enabling it to flex under a load without cracking and to return to the original position after the passage of the load. The type and quantity of binder are important factors that determine the elastic properties of a'mix in addition to the interlock of the aggregate matrix. The mix must be able to withstand the tensile strains caused by loads.

Repeated passage of loads cause fatigue stresses in pavement layers. A long life is possible only if the mix has fatigue resistant properties. The quantity of bitumen has a significant effect on the fatigue resistance of mixes. Up to a point, and provided that other mix requirements are not jeopardised, the higher the binder content, the greater is the fatigue resistance. Dense-graded mixes tend to have greater fatigue resistance than relatively open-graded mixes.

The life of a pavement layer is, inter alia, dependent upon its voids content. A dense mix with low voids content is impermeable to water and air. The presence of water is detrimental to adhesion between aggregates and the binder, and air oxidises the binder. It is, thus, very important that the mix should be dense and highly impermeable.

A mix must be capable of being laid and compacted without undue difficulty. This property of the mix is known as its workability. A careful selection of gradation of aggregates, binder content and laying temperature are necessary to ensure good workability.

Smooth surfaces cause skidding, especially under wet conditions. Aggregates that are prone to polishing under traffic must be avoided in surfacing mixes. The micro and macro texture of the aggregates imparts good skid resistance. Mixes where the voids content is too low will bleed when compressed under load and become slippery. Careful selection of the amount of voids filled with bitumen and remaining air voids is, thus, essential.

Noise from traffic is increasingly becoming a pollution hazard. Part of it is contributed by noise generated at the tyre-road interface. Bituminous surfaces normally create less noise than concrete pavements. Generally, a smooth surface is less noisy.

A highway designer must always look to economy when selecting a pavement material. As bitumen is becoming scarcer and costlier, the selection of the mix has to be carefully done. The initial cost is, of course, very important, but equally important is the life cycle cost. A poorly designed, pavement material may be cheaper initially, but it is false economy to always base decisions on initial cost.

7.3. General Concepts in Mix Design

7.3.1. Stages in Mix Design : Mix design involves the following three stages:

- Preliminary Design
- Job-Mix Formula
- Routine Construction Control

The preliminary design of mixes is done in the laboratory after studying the availability of materials, their suitability and cost. Trial blends can determine the optimum and most economical mix.

The job mix formula translates the laboratory mix into the production process in a plant, adjusted as necessary after laying trials with plant produced mix.

The routine testing and control of materials and mixes is thereafter done to ensure that the final product conforms to the design requirements and is acceptable. In the event of material variations and/or problems with the mix, adjustment to the job mix formula may be required.

7.3.2. Density-voids relationship : An aggregate particle in a bituminous mix has, in its volume the following components (Figs. 7.1 and 7.2) :

1. Volume of voidless solids, V_s
2. Volume of capillary pores which can be filled with water after, say 24 hours of soaking, V_c
3. Volume of capillary pores absorbing bitumen, V_b
4. Volume of capillary pores filled with air $V_a = V_c - V_b$

Let W_S be the weight of solids.

Apparent specific gravity (G_{sa})

$$= \frac{\text{Weight of dry aggregate}}{\text{Volume of aggregate excluding permeable voids}}$$

$$= \frac{W_S}{\left(V_S \gamma_w\right)}$$

Bulk specific gravity (G_{sb})

$$= \frac{\text{Weight of dry aggregate}}{\text{Volume of aggregate including permeable voids}}$$

$$= \frac{W_S}{(V_S + V_C)\gamma_W}$$

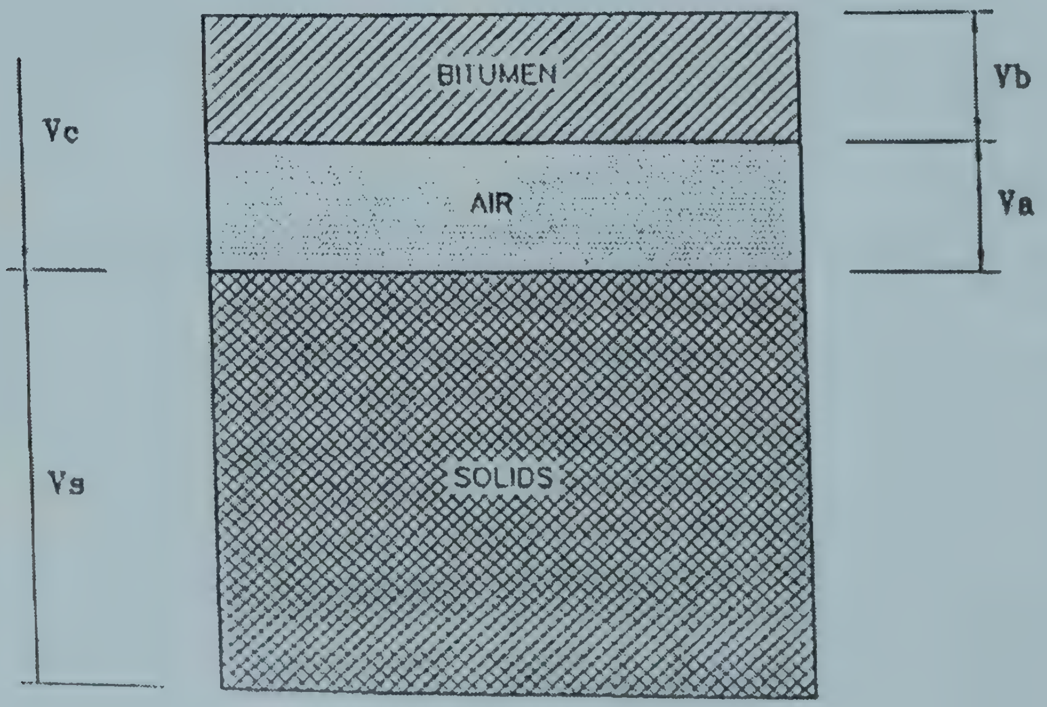


Fig. 7.1. Phase Diagram for an Aggregate-Asphalt System

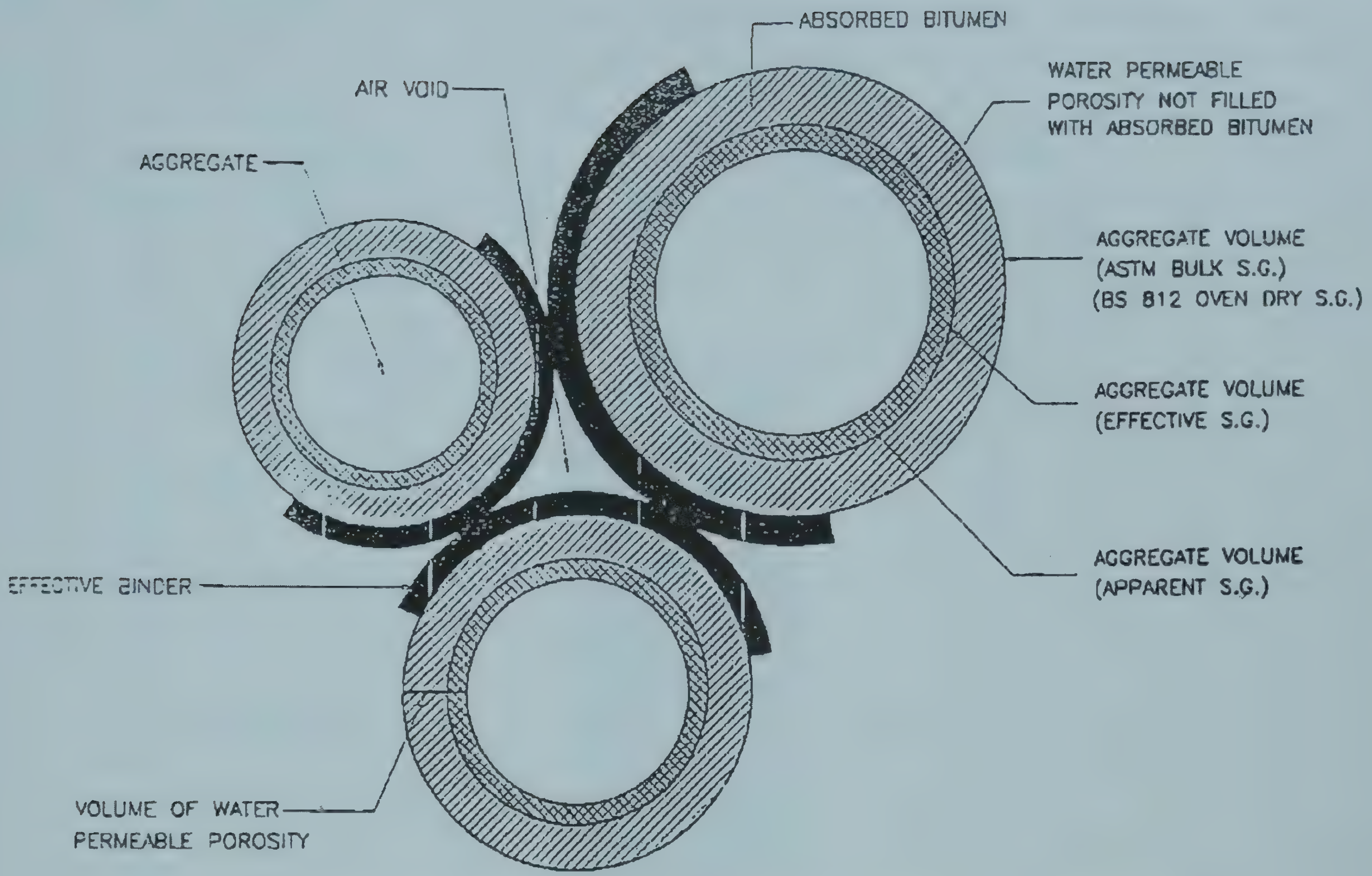

ABSORBED BITUMEN
AIR VOID
AGGREGATE
WATER PERMEABLE POROSITY NOT FILLED WITH ABSORBED BITUMEN
AGGREGATE VOLUME (ASTM BULK S.G.) (BS 812 OVEN DRY S.G.)
AGGREGATE VOLUME (EFFECTIVE S.G.)
AGGREGATE VOLUME (APPARENT S.G.)
EFFECTIVE BINDER
VOLUME OF WATER PERMEABLE POROSITY

Fig. 7.2. Illustrating V.M.A., Air Voids and Effective Bitumen Content in Compacted Bituminous Paving Mixture

Effective Specific gravity (G_{se})

$$= \frac{\text{Weight of aggregate solids}}{\text{Volume of aggregate excluding voids permeable to bitumen}}$$

$$\frac{W_S}{(V_S + V_C - V_b)\gamma_w}$$

$$= \frac{W_s}{(V_s + V_c - V_b)\gamma_w}$$

Because it is often found that the V_b is approximately half V_c, the effective specific gravity can be approximated as : ½ [Apparent specific gravity, G_{sa} + Bulk specific gravity, G_{sb}].

When a number of aggregate fractions are blended, the average specific gravity (G_{ag}) of the combined aggregates can be calculated from:

$$G_{ag} = \frac{100}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \frac{P_3}{G_3} + \dots\dots\dots\dots}$$

Where G_{ag} = Average specific gravity of the combined aggregate

$G_1, G_2, G_3 \dots$ = Specific gravities of the various aggregates 1, 2, 3 ....

$P_1, P_2, P_3 \dots$ = Per cent by weight of aggregates 1, 2, 3 .... in combined aggregate

In order to understand the weight-volume relationships in a mix, Fig.7.3 will be of help. The following notations will be used (bulk and effective where applicable):

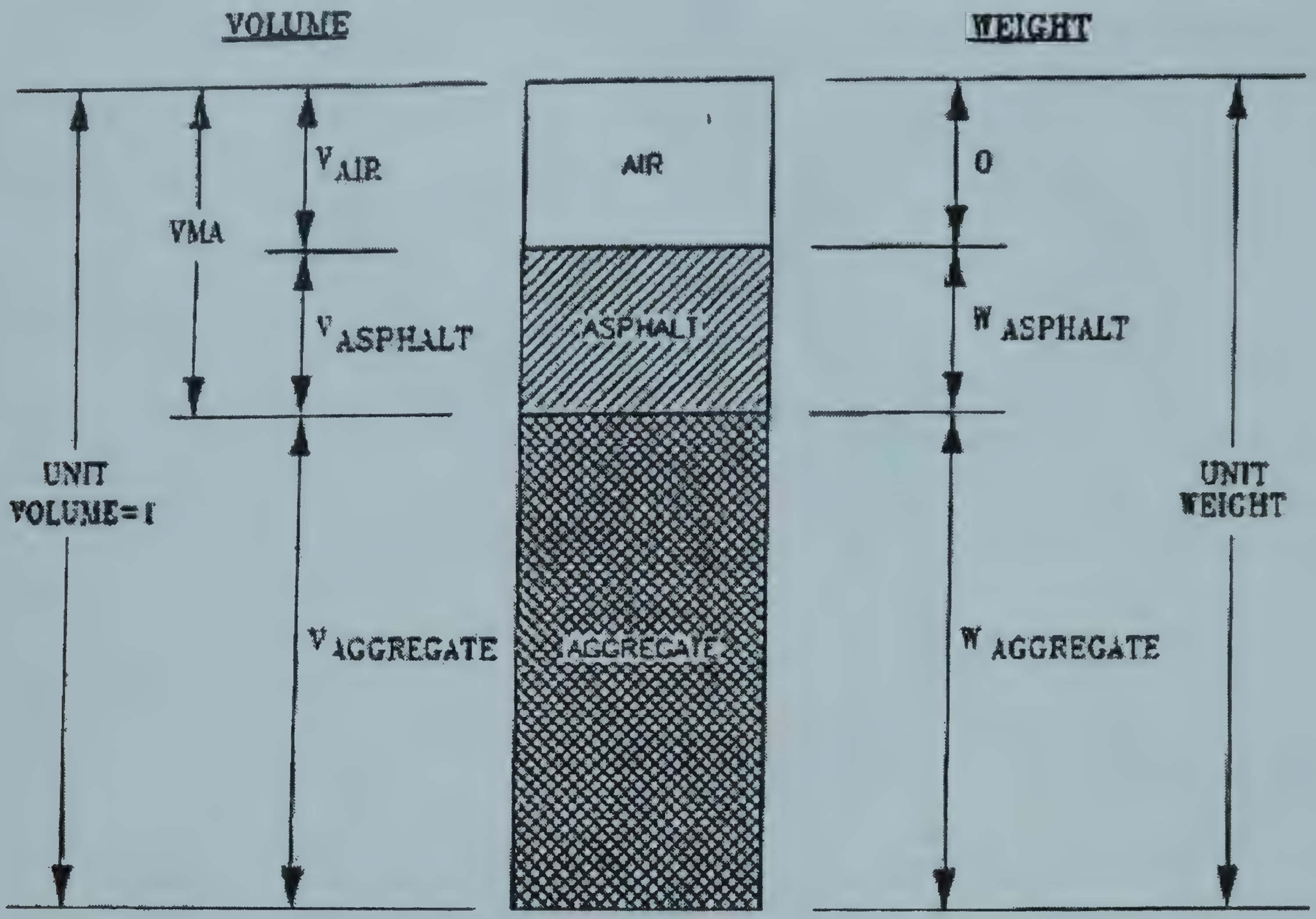

VOLUME
WEIGHT
V AIR
VMA
V ASPHALT
UNIT VOLUME=1
V AGGREGATE
AIR
ASPHALT
AGGREGATE
0
W ASPHALT
UNIT WEIGHT
W AGGREGATE

Fig. 7.3. Weight-Volume Relationship of a Bitumen Mix

Bulk (for no bitumen absorption)			**Effective (for some bitumen absorption)**
W	=	Weight of a sample of mixture (gm)	Same
W_{ac}	=	Weight of bitumen (binder) (gm)	Same
W_{ca}	=	Weight of coarse aggregates (gm)	Same
W_{fa}	=	Weight of fine aggregates (gm)	Same
W_{mf}	=	Weight of mineral filler (gm)	Same
W_{ag}	=	Weight of total aggregates and filler (gm)	Same
γ_w	=	Density of water = 1 gm per cc	Same
γ_m	=	Bulk density of mix sample(gm/cc)	Same
γ'_{mob}	=	Maximum theoretical denstiy of mix (gm/cc)	γ'moe
G_{ac}	=	Specific Gravity of bitumen	Same
G_{CAB}	=	Specific Gravity of coarse aggregates	G_{cac}
G_{fab}	=	Specific Gravity of fine aggregates	G_{fae}
G_{mf}	=	Specific Gravity of mineral filler	Same
G_{agb}	=	Average Specific Gravity of the aggregates	G_{age}

V_{cab}	=	Volume of coarse aggregates (cc)	V_{cac}
V_{fab}	=	Volume of fine aggregates (cc)	V_{fac}
V_{mf}	=	Volume of mineral filler (cc)	Same
V_{acb}	=	Volume of bitumen (cc)	V_{ace}
V_{vb}	=	Volume of voids (cc)	V_{vc}
V	=	Total volume of specimen (cc)	Same

Then : $W = W_{ac} + W_{ca} + W_{fa} + W_{mf}$

$$V = V_{ac} + V_{ca} + V_{fa} + V_{mf} + V_{v}$$

$$= \frac{W_{ac}}{G_{ac}} + \frac{W_{ca}}{G_{ca}} + \frac{W_{fa}}{G_{fa}} + \frac{W_{mf}}{G_{mf}} + V_{v}$$

For specimens having a dense impermeable surface, the bulk density is determined by the ratio of the eight of specimen in air and the loss of weight when fully immersed in water.

Thus: $\gamma_m = \frac{W}{V}$

$$= \frac{W}{W - W_{sw}}$$

where W_{sw} = weight of specimen in water

If the specimen is of true size whose dimensions can be accurately measured, the bulk density can calculated by the known volume

$$\gamma_m = \frac{W}{V}$$

$$\gamma_m = \frac{W}{(\frac{\pi}{4})d^2 h}$$

where d is the diameter of the specimen and h, its height

If a specimen has an open permeable surface, it is necessary to coat the specimen with paraffin wax so that water is not absorbed. The bulk density then is:

$$\gamma_m = \frac{W}{V}$$

$$\frac{W}{W_{sa} - W_{sw} - \frac{(W_{sa} - W)}{G_p}}$$

Where W = Weight of specimen in air

W_{sa} = Weight of paraffin wax coated specimen in air

W_{sw} = Weight of paraffin wax coated specimen in water

G_p = Specific gravity of paraffin wax

If a specimen could be compacted until no air voids are left, maximum theoretical density (γ_{mo}) would be obtained. Its value is:

BULK (Bitumen not absorbed)	EFFECTIVE (Bitumen absorbed)
$\gamma_{mob} = \frac{W}{V - V_{vb}}$ Where V_v = Volume of air voids $= \frac{W}{V_{ac} + V_{cab} + V_{fab} + V_{mf}}$ $= \frac{W}{\frac{W_{ac}}{G_{ac}} + \frac{W_{ca}}{G_{cab}} + \frac{W_{fa}}{G_{fab}} + \frac{W_{mf}}{G_{mf}}}$	$\gamma_{moe} = \frac{W}{V - V_{ve}}$ $= \frac{W}{V_{ac} + V_{cae} + V_{fae} + V_{mf}}$ $= \frac{W}{\frac{W_{ac}}{G_{ac}} + \frac{W_{ca}}{G_{cae}} + \frac{W_{fa}}{G_{fae}} + \frac{W_{mf}}{G_{mf}}}$
where W = Total weight of sample = $W_{ac} + W_{ag}$	
The average specific gravity of the combined aggregates	
BULK	**EFFECTIVE**
$G_{agb} = \frac{W_{ag}}{\frac{W_{ca}}{G_{cab}} + \frac{W_{fa}}{G_{fab}} + \frac{W_{mf}}{G_{mf}}}$	$G_{age} = \frac{W_{ag}}{\frac{W_{ca}}{G_{cae}} + \frac{W_{fa}}{G_{fae}} + \frac{W_{mf}}{G_{mf}}}$
Substituting, Maximum theoretical density	
$\gamma_{mob} = \frac{W}{\frac{W_{ac}}{G_{ac}} + \frac{W_{ag}}{G_{agb}}}$	$\gamma_{moe} = \frac{W}{\frac{W_{ac}}{G_{ac}} + \frac{W_{ag}}{G_{age}}}$
The per cent maximum density	
$= \frac{\gamma_m}{\gamma_{moe}} \times 100$ Per cent air voids $= \frac{V_{vb}}{V} \times 100 = 100 - \frac{\gamma_m}{\gamma_{mob}} \times 100$ $= \frac{V - V_{acb} - V_{cab} - V_{fab} - V_{mf}}{V} \times 100$	$= \frac{\gamma_m}{\gamma_{moe}} \times 100$ $\frac{V_{ve}}{V} \times 100 = 100 - \frac{\gamma_m}{\gamma_{moe}} \times 100$ $= \frac{V - V_{ace} - V_{cae} - V_{fae} - V_{mf}}{V} \times 100$
Volume occupied by any constituent material, say bitumen	

$$V_{ac} = \frac{W_{ac}}{G_{ac}}$$

$$= \frac{\text{Per cent weight of asphaltic cement (i.e., bitumen)} \times W}{G_{ac}}$$

Percentage volume of air voids

$$= 100 - \% V_{ac} \% V_{ca} - \% V_{fa} - \% V_{mf}$$

$$= 100 - (\gamma_m/\gamma_{mo}) \text{ x } 100$$

Percentage volume of voids in mineral aggregates, VMA

$$= 100 - \% V_{ag}$$

$$= 100 \ \frac{\text{Per cent weight of aggregates x } W}{V \text{ x } Gag}$$

Percentage aggregate voids filled with bitumen = $\dfrac{\% V_{ac}}{\text{\% aggregate voids}}$

Various mix parameters for the analysis of a compacted mix are given below:

Mix Parameters (for some bitumen absorbed)	For no bitumen absorbed Gse = Gsb
*Pba = (Gse - Gsb) / (Gse x Gsb) x 100 x Gb	= 0
Pbe = Pb - (Pba x Ps) / 100	= Pb
Gmm = 100 / (Ps/Gse+Pb/Gb)	= 100/(Ps/Gsb + Pb/Gb)
Vbe = (Pbe x Gmb) / Gb	= (Pb x Gmb) / Gb
Va = (1-Gmb/Gmm) x 100	= (1-Gmb / Gmm) x 100
VMA=Va + Vbe	= Va + Vb
Vf = Vbe / VMA x 100	= Vb / VMA x 100

Where:

Pb = Total bitumen as percentage of total weight of mix.

Pba = Bitumen absorbed as percentage of total weight of aggregate

Pbe = Effective bitumen as percentage of total weight of mix

Ps = Total aggregate as percentage of total weight of mix

[NB. Pb + Ps = 100 and VMA + Vs = 100)

Gb = Specific gravity of bitumen

Gmb = Bulk specific gravity of compacted mix

Gmm = Maximum theoretical specific gravity of mix

Gsb = Bulk SG of combined aggregate

Gsa = Apparent SG of combined aggregate

Gse = Effective SG of combined aggregate

Vmb = Bulk volume of the compacted mix

Vbe = Effective bitumen content by volume as per cent Vmb

---

*Assume that half the pores in the combined aggregate particles are filled with absorbed bitumen.

Va = Air voids volume as percent of Vmb

VMA = Intergranular voids volume as per cent Vmb

Vrnm = Minimum (voidless) theoretical volume of mix

Vb = Total bitumen content by volume as per cent Vmb

Vba = Absorbed bitumen volume as percent Vmb

Vsb = Bulk volume of combined aggregate as per cent Vmb

Vse = Effective volume of combined aggregate as per cent Vmb

Vf = Part of intergranular void filled with bitumen as per cent VMA

The volume components above are illustrated in Fig. 7.3

7.4. Mix Design Methods

Mix design methods are specified in the construction specifications. Though, there are many design methods being followed, the basic principle behind them is to arrive at the optimum binder content, given the gradation selected and the mechanical properties desired. The most common method being practised is the Marshall method, although the Hveem method is also in use. The Hubbard-Field and the Smith Triaxial II are the other methods. The Marshall Method is specified in the Indian specifications and is described in detail.

7.5. The Marshall Method

7.5.1. Origin and current status : The Marshall Method was originally developed by Bruce Marshall of the Mississippi State Highway Department. The method is now standardised by many organisations, including the ASTM, AASHTO, US Corps of Engineers and British Standards Institution. The Ministry's Specifications and Indian Roads Congress also refer to this method. The method is applicable only to hot-mix bituminous paving mixtures, using penetration grade bitumen and containing aggregates with a maximum size of 26.5 mm. If the material contains fractions retained on 26.5 mm sieve, such a fraction may be replaced by aggregates passing 26.5 mm sieve and retained on the 22.4 mm sieve. Alternatively, there is a modified Marshall method described in Asphalt Institute's MS-2, which may be used for materials containing higher size aggregates.

7.5.2. Outline of the method : The Marshall method uses standard test specimens of height 64 mm and diameter 102 mm. The specimens are prepared using a standard procedure for heating, mixing and compacting the mixture. Compaction is done by imparting 50 or 75 blows on each side of the specimen. 50 blows are used for medium traffic roads and 75 blows are used for heavily trafficked roads. The principal features of the method are a density-voids analysis and a stability-flow test of the compacted specimens. The stability is a measure of the strength of the mixture. It is the maximum load resistance in Newtons, which it will develop at 60°C when tested in the standard Marshall equipment (Fig. 7.4). The flow value is the total deformation in units of 0.25 mm, occurring in the specimen between no load and maximum load during the test.

The test specimens are prepared with varying bitumen content in 0.5 per cent increments over a range that gives a well-defined maximum value for specimen density and stability. At least two bitumen content values should be above and two values below this maximum point. Usually, 5 or 6 values of binder content are selected. For each bitumen content normally three test specimens are prepared and an average of three specimens obtained.

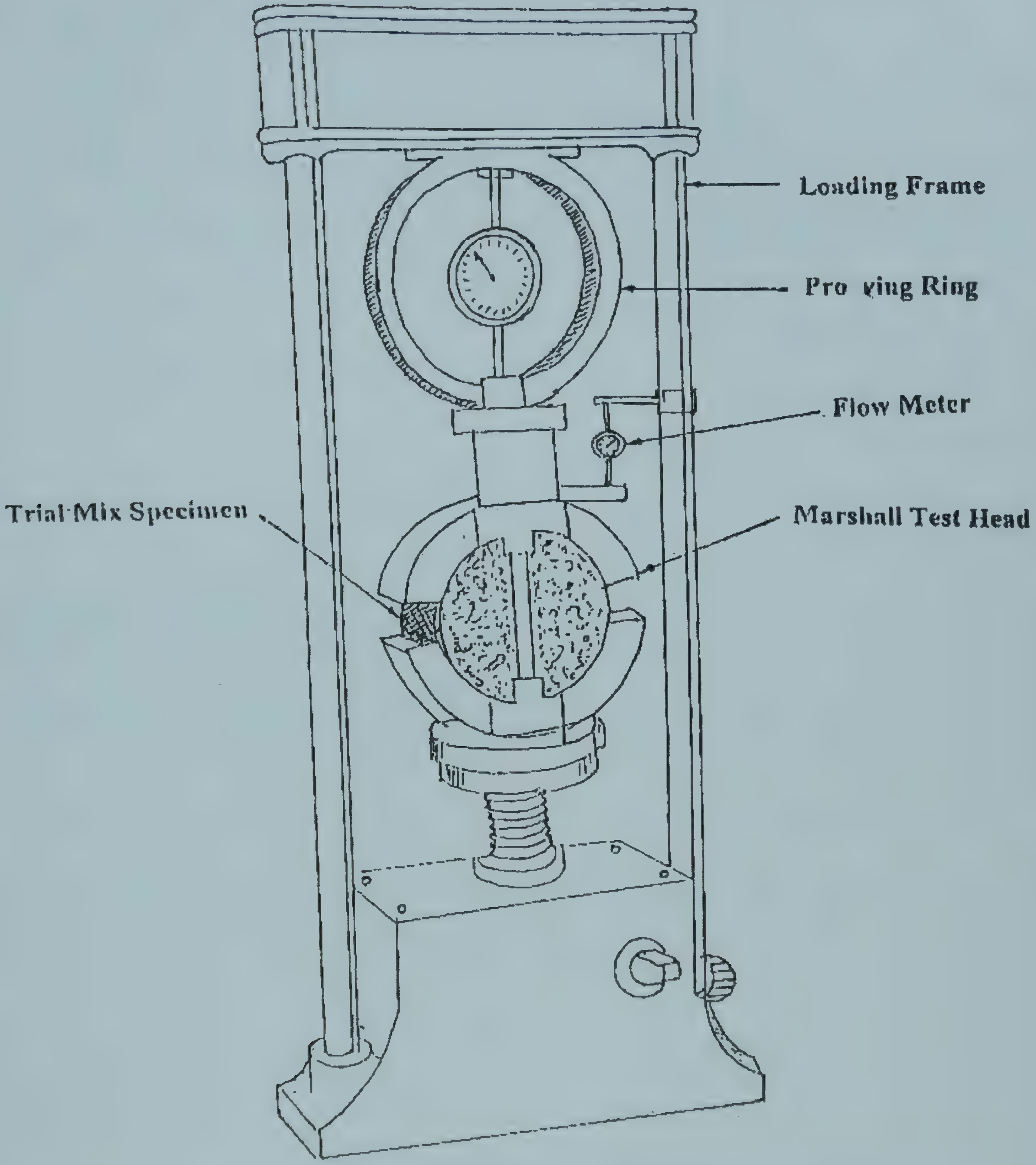

Loading Frame
Pro ving Ring
Flow Meter
Trial Mix Specimen
Marshall Test Head

Fig. 7.4. Marshall Test Apparatus

The test machine is an electrically powered testing device designed to apply loads at a constant rate in of 5 cm per minute and provided with a calibrated proving ring to measure the load. The maximum at failure is the stability value. A flow meter records the deformation at the maximum load when failure occurs.

7.5.3. Analysis of results : The test results give data for performing a density-voids analysis.

The following graphs are drawn:

1 Unit .weight vs bitumen content

2. Marshall stability vs bitumen content
3. Percentage air voids in total mix vs bitumen content
4. Percentage voids in mineral aggregates vs bitumen content
5. Flow value vs bitumen content.

Typical graphs are illustrated in Fig. 7.5.

From these curves, the bitumen content is obtained for the following conditions:

1. Point of maximum stability
2. Point of maximum density
3. Point of 4 per cent air voids in total mix

The optimum binder content is the average value of the above three, and is used in the design, provided it satisfies all other design criteria.

At the optimum bitumen content, it is desirable to prepare further trial samples for purposes of checking the design parameters, like, voids in the mineral aggregate, air void content in the mix and retained stability.

For National Highways in India, where traffic is of a high order, the minimum stability value specified is 8000 N with specimens compacted with 75 blows on each side. The per cent air voids is in the range of 3 to 5. The flow value in mm is in the range of 2 to 4.

7.6. Job Mix Formula

After the laboratory investigations and Marshall tests are carried out, the next stage is the formulation of the job mix formula. In this stage of the work, the results from the laboratory analysis are translated into the actual working of a mixing plant. The job mix formula enables the plant operator to feed aggregates of various sizes, filler and binder into the plant so that the final mix is as close as possible to the laboratory design mixes.

The job mix formula is determined tentatively on the basis of test samples taken from the aggregates delivered and stockpiled and processed from the hot bins of the plant to be used. Refinements are made after the plant is in regular operation and the characteristics of the actual mix laid have been determined from the samples.

7.7. An Illustrative Example of Density - Voids Relationships

A specimen of asphaltic concrete has a height of 6.20 cm and a diameter of 10.16 cm. The weight of the compacted specimen (uncoated) in air is 1174.7 gms and in water the weight is 668.4 gms. When coated with paraffin wax, its weight in air is 1220.9 gms and its weight when immersed in water is 664.4 gms.

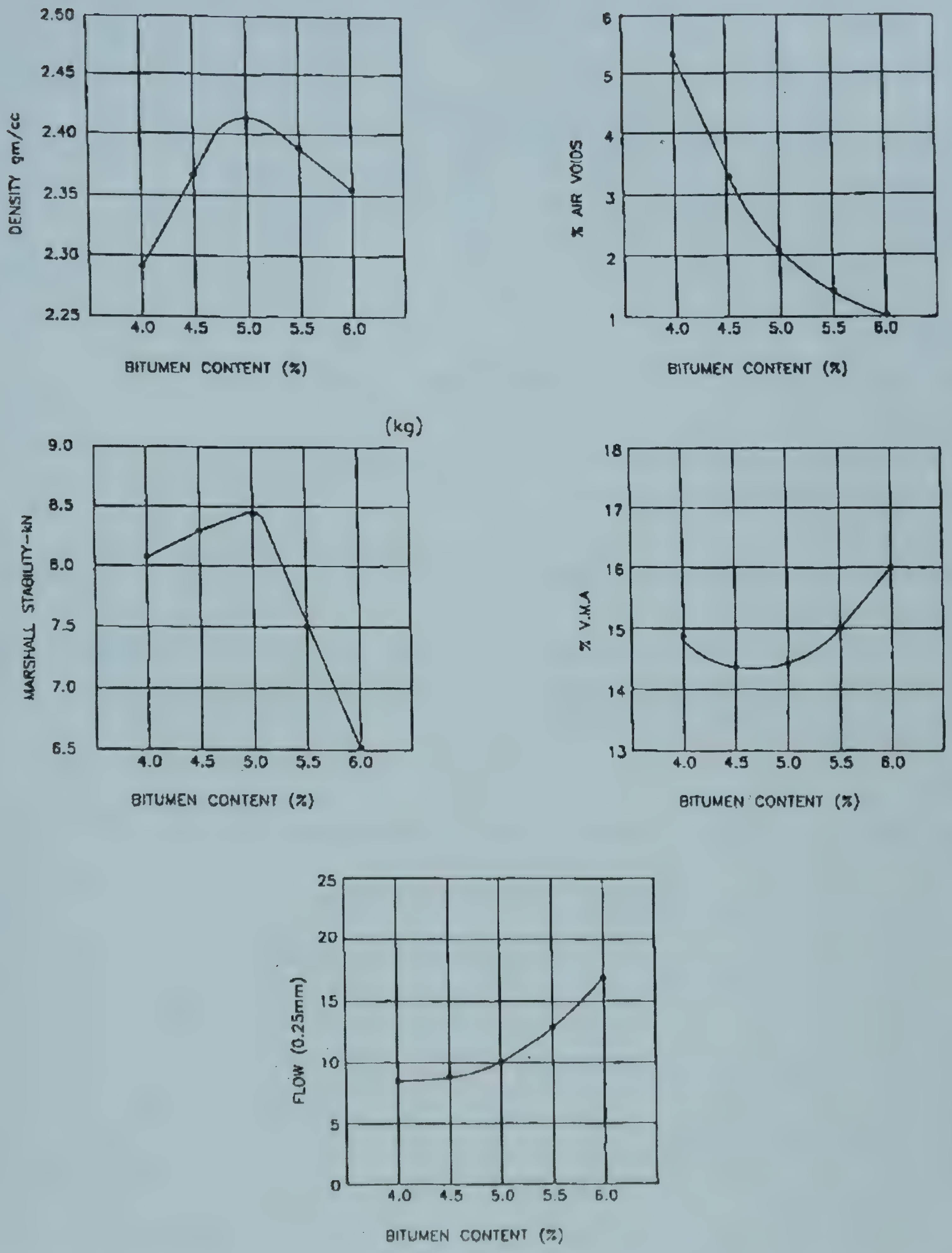


Fig. 7.5. Typical Test Property Curves for Hot-Mix Design Data by the Marshall Method

The specific gravity of paraffin wax is 0.90. The analysis of the specimen yielded the following:

	Material	Specific Gravity		Mix composition (% by weight of total. mix)	Aggregate Composition (% by weight of total aggregates)
		BULK	APPARENT		
1.	Asphaltic Cement (Bitumen)	1.02	1.02	6.0	
2.	Coarse Aggregates	2.58	2.70	52.0	55.3
3.	Fine Aggregates	2.72	2.80	34.6	36.8
4.	Mineral Filler	2.70	2.70	7.4	7.9
				100.0	100.0

Calculate

1. Bulk density of specimen by uncoated specimen procedure and immersion test.
2. Bulk density bf specimen from specimen dimensions.
3. Bulk density of specimen by paraffin wax coated sample procedure.
4. Average specific gravity, of the aggregates.
5. Maximum theoretical density.
6. Bulk density as per cent of maximum density.
7. Percent voids in compacted mix.
8. Per cent volume occupied by asphaltic cement (i.e., bitumen), coarse aggregates, fine aggregates, mineral filter.
9. Per cent volume of voids in mineral aggregates (VMA).
10. Per cent aggregate voids filled with asphalt.

Solution

1. Bulk density of specimen by uncoated specimen immersed in water

$$G_{mb} = \frac{W}{W - W_{sw}} = \frac{1174.7}{1174.4 - 668.4}$$

$$= \frac{1174.7}{506.3} = 2.320 \text{ gm/cc}$$

2. Bulk density from dimensions of specimen

$$G_{mb} = \frac{1174.7}{\frac{\pi \times 10.16 \times 10.16 \times 6.20}{4}}$$

$$= 2.337 \text{ gm/cc}$$

3. Bulk density from paraffin wax coated specimen

$$G_{mb} = \frac{W_{sa}}{W_{sa} - W_{sw} - \frac{(W_{sa} - W)}{G}} = \frac{1174.7}{(1220.9-664.4) - \frac{(1220.9-1174.7)}{0.90}}$$

$$= \frac{1174.7}{505.2} = 2.325 \text{ gm/cc}$$

4. Average specific gravity

$$G_{sb} = \frac{W_{ag}}{\frac{W_{ca}}{G_{ca}} + \frac{W_{fa}}{G_{fa}} + \frac{W_{mf}}{G_{mf}}}$$

$$= \frac{100}{\frac{55.3}{2.58} + \frac{36.8}{2.72} + \frac{7.9}{2.70}} = 2.64$$

5. Maximum theoretical density

$$= \frac{W}{\frac{W_{ac}}{G_{ac}} + \frac{W_{ag}}{G_{ag}}}$$

$$= \frac{1174.7}{\frac{0.06 \times 1174.7}{1.02} + \frac{0.94 \times 1174.7}{2.64}} = 2.41 \text{ gm/c.c}$$

6. Bulk density as per cent of maximum theoretical density

$$= \frac{2.32}{2.41} \times 100 = 96.3\%$$

(Note : The values of bulk density from steps 2 or 3 will yield slightly different results.)

7. Percent air voids in compacted mix.

$$= \frac{V - V_{ac} - V_{ca} - V_{ja} - V_{mf}}{V} \times 100 = 3.7\%$$

Where; $V = 1174.7/2.32$

$V_{ac} = 1174.7 \text{x } 0.06/1.02$

$V_{ca} = 1174.7 \text{x } 0.52/2.58$

$V_{fa} = 1174.7 \text{ x } 0.346/2.72$

$V_{mf} = 1174.7 \text{x } 0.074/2.70$

This is also given by:

$$100 - \frac{\gamma_m}{\gamma_{mo}} \times 100 = 100 - \frac{2.32}{2.41} \times 100$$

$$= 100 - 96.3 = 3.7\%$$

8. Per cent volumes occupied by constituents

$$\%V_{ac} = \frac{6.00 \times 2.32}{1.02} = 13.7\%$$

$$\%V_{ca} = \frac{52.0 \times 2.32}{2.58} = 46.8\%$$

$$\%V_{fa} = \frac{34.6 \times 2.32}{2.72} = 29.5\%$$

$$\%V_{mf} = \frac{7.4 \times 2.32}{2.70} = 6.3\%$$

$$\%V_{ag} = \frac{94.0 \times 2.32}{2.64} = 82.6\%$$

9. Per cent volume of voids in mineral aggregate (VMA)

$$= 100 - \frac{\%\ \text{weight of aggregates} \times W}{G_{ag} \times V}$$

$$= 100 - \frac{0.94 \times 1174.7 \times 2.32}{2.64 \times 1174.7}$$

$$= 100\text{-}82.6 = 17.4\%$$

10. Per cent of aggregate voids filled with bitumens

$$= \frac{\text{Per cent of asphaltic cement (i.e., bitumen) in mix}}{\text{Per cent of Voids in mineral aggregates}} \times 100$$

$$= \frac{13.7}{17.4} \times 100 = 78.7 \text{ per cent}$$

When account is taken of bitumen absorption, it is found that the actual air voids are 5.3 per cent and not 3.7 per cent.

7.8. Design of Mixes Using Polymer Modified Bitumen

When polymer modified bitumen (PMB) is used as a binder in dense or semi-dense hot-mix hot-laid bituminous mixes, the properties of a hot-mix should meet the requirements laid down in Table 7.1 (as per IRC:SP:53).

Table 7.1. Requirements of Mix Prepared with Modified Bitumen

Sl. No.	Properties	Requirement			Test Method
		Hot Climates	Cold Climates	High Rainfall	
1.	Marshall Stability at 60°C, kg, Minimum	1200	1000	1200	ASTM: D1559-1979
2.	Marshall Flow at 60°C, mm	2.5-4.0	3.5-5.0	3.0-4.5	ASTM: D1559-1979
3.	Marshall Quotient, kg/mm		250-500		Stability/Flow
4.	Voids in compacted mix, per cent		3.0-5.0		--
5.	Requirement of retained stability after 24 hours in water at 60°C, per cent, Minimum	90	95	100	ASTM: D1075-1979
6.	Coating with aggregate, per cent	95	95	100	AASHTO T182

The mix design for dense-graded bituminous mixes is done in the same manner as done for ordinary bitumen by Marshall Method of Mix Design (ASTM D1559).

CHAPTER 8

CONSTRUCTION

8.1. General

For the various types of bituminous construction works, a brief description, purpose/use and requirements of bituminous materials and the mixes were given in Chapter 4. This Chapter deals with various pre-construction activities and salient construction aspects of each type of bituminous construction as given under two broad groups (A&B) of construction methods

A. Sprayed or Penetration Layer Bituminous Constructions

1. Prime Coat
2. Tack Coat
3. Bituminous Penetration Macadam
4. Built-up Spray Grout
5. Surface Dressing
6. Liquid Seal Coat
7. Fog Spray

B. Pre-mix Methods of Construction/Plant Mixes

1. Bituminous Macadam
2. Dense-Graded Bituminous Material
    - (i) Dense Bituminous Macadam
    - (ii) Semi-Dense Bituminous Concrete
    - (iii) Bituminous Concrete
3. Open-Graded Premix Surfacing
4. Close-Graded Premix Surfacing/Mix Seal Surfacing
5. Premix Seal Coat
6. Mastic Asphalt
7. Slurry Seal
8. Recycling of Bituminous Pavement
9. Stone Mastic Asphalt
10. Bituminous Cold Mix (including Gravel Emulsion)
11. Sand Asphalt Basecourse
12. High Performance Base
13. Use of Polymer and Rubber Modified Bitumen

The equipment to be used for the construction of above types of bituminous works has already been described in Chapter 6. The remainder of this Chapter, therefore, outlines only the salient construction aspects.

An extremely important aspect of all bituminous construction works is their adverse impact on the environment; the necessary steps to be taken towards protection of the environment are detailed ***Appendix-14***.

8.2. Pre-Construction Activities

8.2.1. Supply and storage of aggregates

8.2.1.1. Site selection : The storage of aggregates requires a large area of land the use of which must be carefully planned in advance. Not only does there have to be sufficient space for the aggregates themselves, but there must also be allowance for haulage and loading equipment to manoeuvre between stockpiles when delivering and re-handling the aggregates. Stockpiles must be well spaced to ensure against contamination of stockpiles by aggregates of different sizes and/or gradings.

It is important that the area selected for stockpiling is well-drained and is surfaced with a well-compacted and carefully levelled material capable of withstanding the action of heavy equipment without rutting or generating mud. It may be necessary to import a good gravel material to the stockpile area and level and compact it to form, a firm base for stockpiling. The material may be treated as sub-base material and treated with water, premixed before levelling and compacting.

8.2.1.2. Material handling : The surface of an aggregate stockpile, which is continuously changing as material is added and/or removed, is subject to segregation due to the tendency of the larger size particles to roll down towards the base to a greater extent than smaller sizes. When extracting material from such a stockpile with a mechanical shovel, it is necessary to dig well into the base of the stockpile to aid remixing. A skilled loader. operator is an important factor in making sure that segregated material is not placed in the cold bins. Clear marking of aggregate size at stockpiles and on storage bins will help to avoid accidental placing of the wrong size in a stockpile or in a bin.

8.2.1.3. Cold feed arrangement : The cold feed arrangement is the first component of the mixing plant. It consists of two to five compartments, one for each nominal aggregate size (Fig. 8.1). The compartments are open-top bins, which are usually fed by a front-end loader or a clamshell bucket crane, which usually loads the material directly from stockpile. Alternatively, a tunnel arrangement under the stockpiles can also be provided. Materials are stockpiled over the tunnel by a belt-conveyor, truck, front-end loader or crane. Another possible arrangement is a series of bunkers or large bins, from which aggregates may be loaded by drag-line arrangement. Bins are normally covered with screens to restrict the entry of large boulders in the bin which may eventually choke the openings of the bin.

8.2.1.4. Filler : Filler is a fine material, often cement or slaked lime or crushed limestone, which is likely to be vulnerable to moisture and the action of wind. It is usually necessary to handle it separately preferably to store it in a covered bunker (Fig. 8.2).

8.2.2. Storage and handling of bitumen

8.2.2.1. Bulk supply : The bitumen supplied in bulk is received in tankers and transferred to fixed, purpose-built storage tanks. The site selected for storage of bulk bitumen should be as close to the mixing plant as practicable, but capable of accommodating the unhindered movement of trucks.

8.2.2.2. Bitumen in Drums : For small jobs, bitumen may be delivered and stored in drums (Fig.8.3). In such cases, equipment must be available at the site capable of handling drums and hoisting them to the decanting point for transfer of the bitumen to storage tanks or directly to a mobile bitumen boiler.

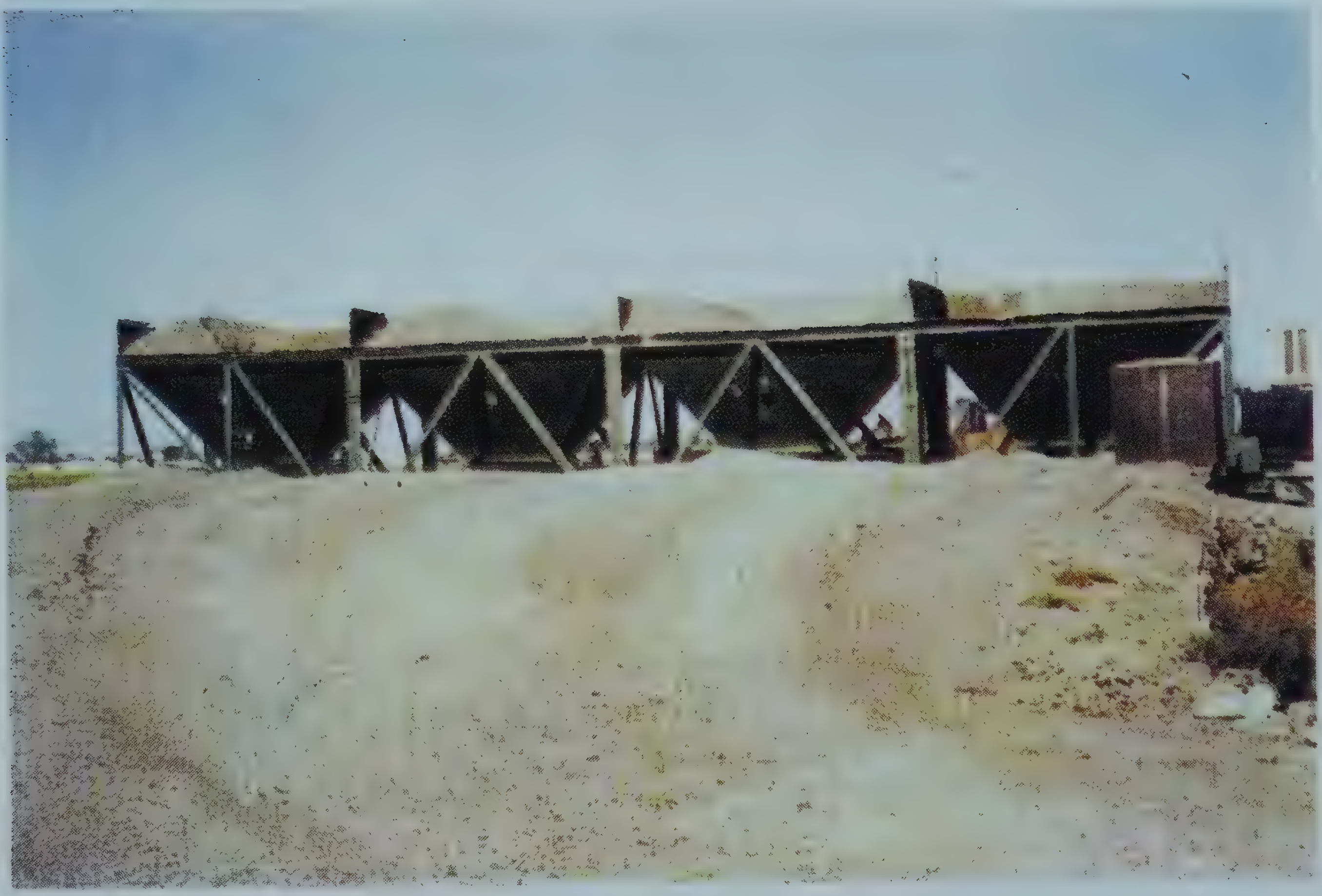


Fig. 8,1. Four Open-Top Bins for Different Aggregate Sizes

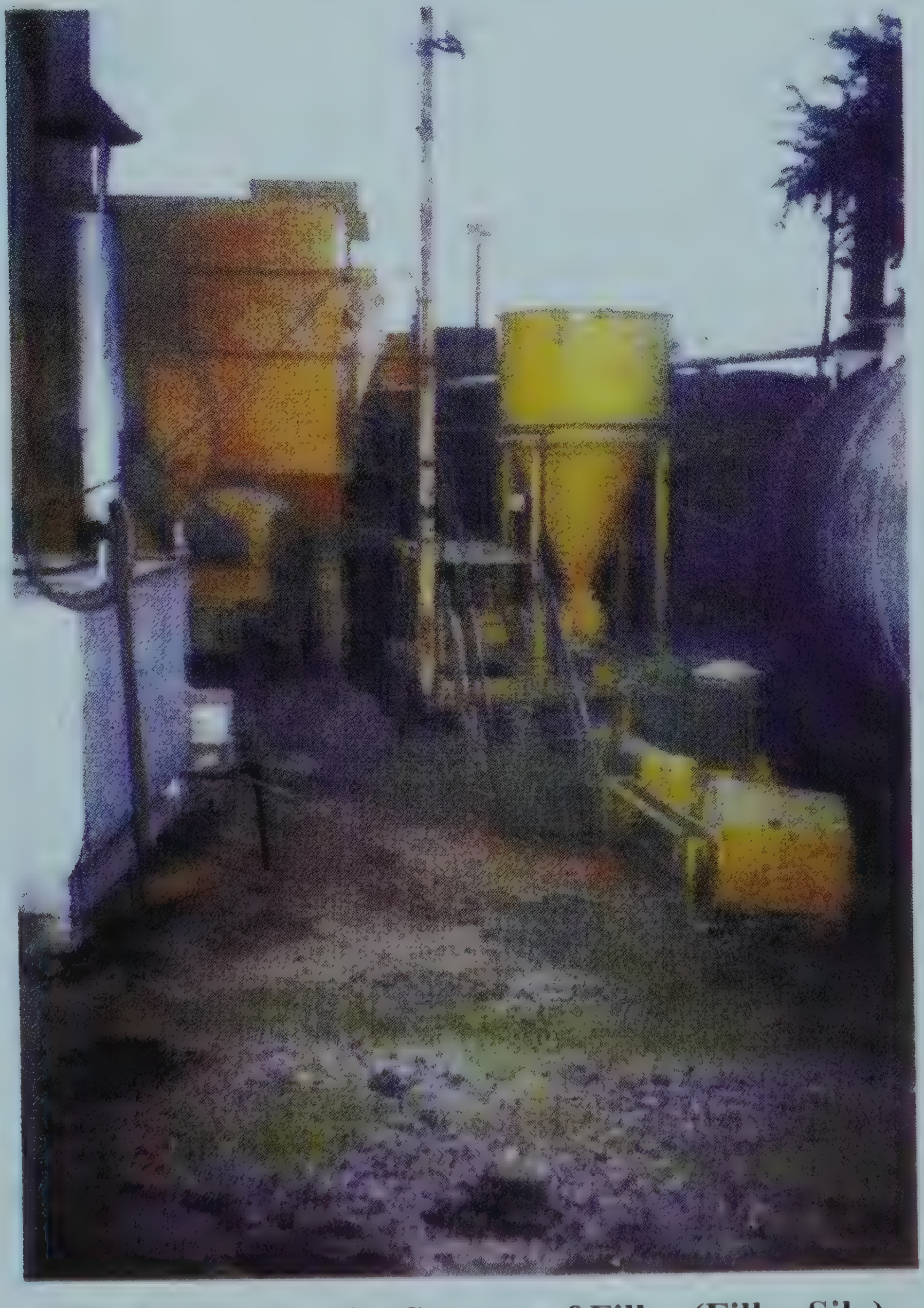


Fig. 8.2. Bunker for Storage of Filler (Filler Silo)

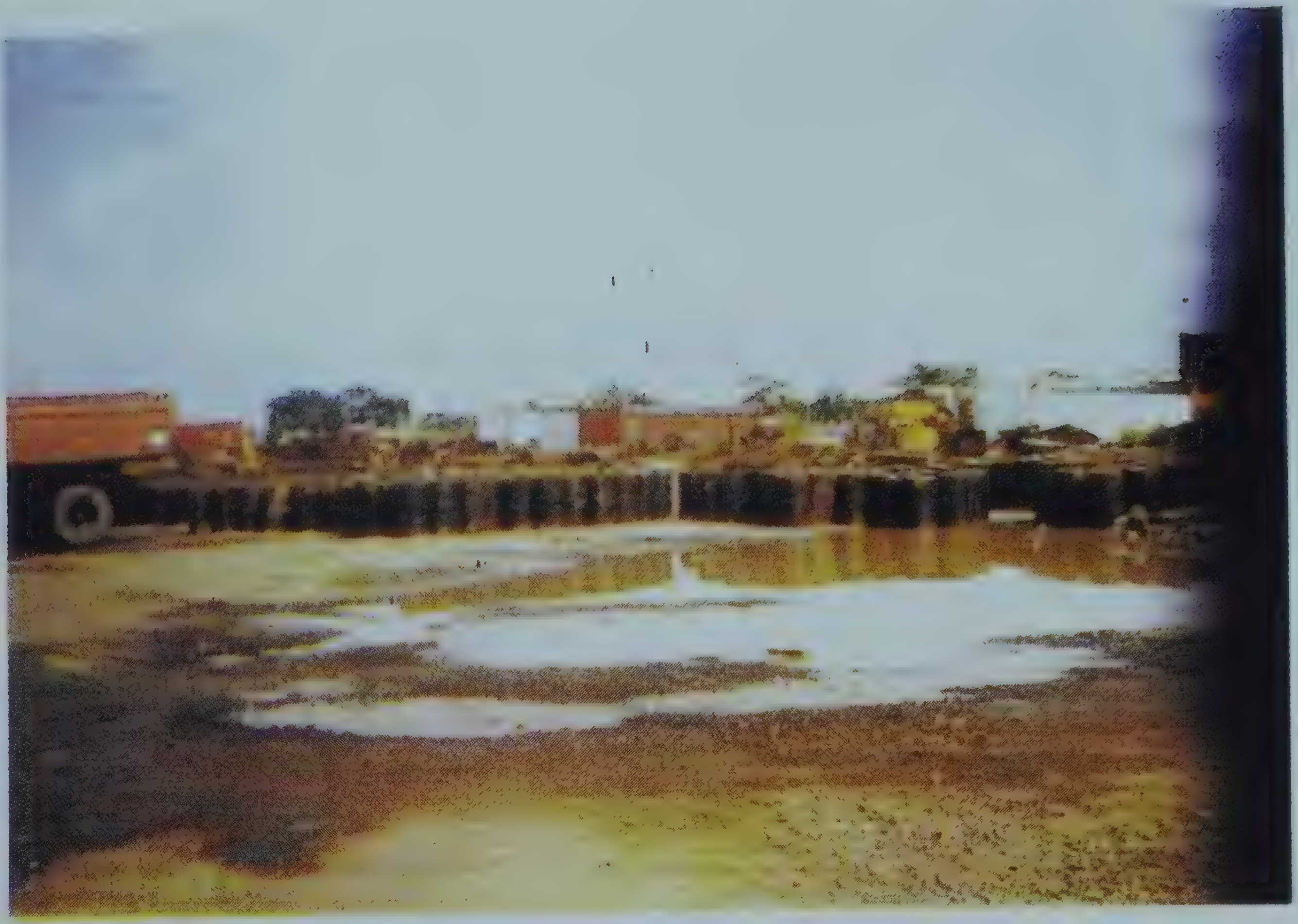


Fig. 8.3. Bitumen Stored in Drums for Small Jobs

8.2.2.3. Bitumen storage tanks : Bitumen storage tanks (Fig. 8.4) should have adequate capacity to ensure uninterrupted binder supply to the mixer. The details of heating arrangement have been described in Chapter 6.

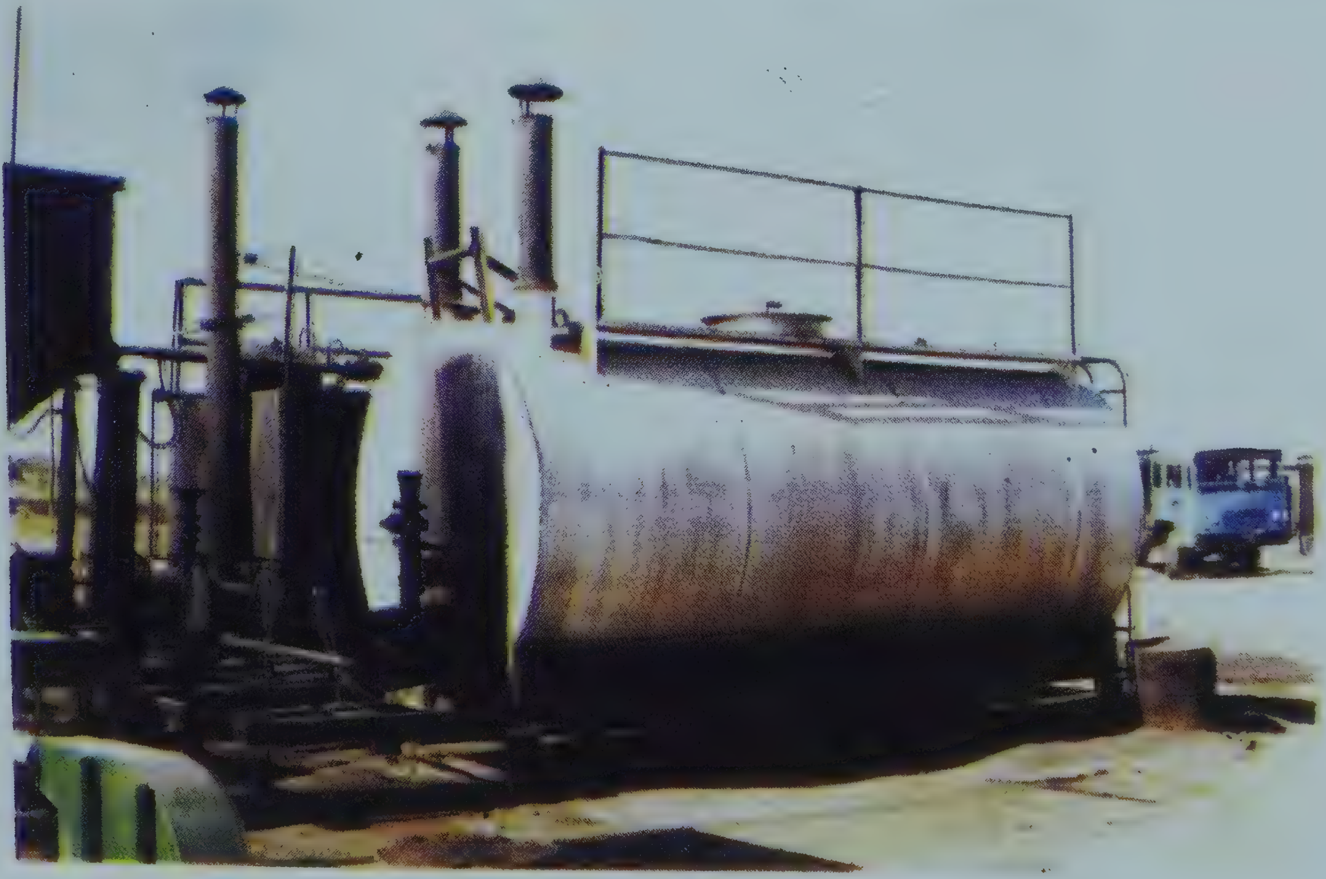


Fig. 8.4. Bitumen Storage Tanks

8.2.3. Traffic control

8.2.3.1. Least interference to traffic to be ensured : Bituminous construction work should be carried out so as to ensure the least interference with the flow of public traffic. The control of traffic is particularly important when the works involve maintenance, rehabilitation and improvements to existing roads. The most expedient measure is to provide and maintain a temporary diversion away from the carriageway where work is going on. If this is impractical, arrangements should be made to pass traffic along a part of the carriageway under improvement. For example, if a two-lane carriageway is to be improved the work should be done in parts. Initially, one-lane should be taken up for overlay while traffic moves on the second lane (Fig. 8.5). If construction or maintenance works are to be carried out during late night or early mornings, all barricades, safety cones and other safety devices should have reflective paints and provided with reflectors. Treated shoulders on the sides of the carriageway can give additional temporary traffickable width for vehicles to manoeuvre. Such work should normally be limited to stretches of about 500 metres in length. When a two-lane carriageway is to be widened to four-lanes (divided), the work can be conveniently done by constructing the additional carriageway first and only starting the improvements on the existing carriageway after opening the new carriageway to traffic.

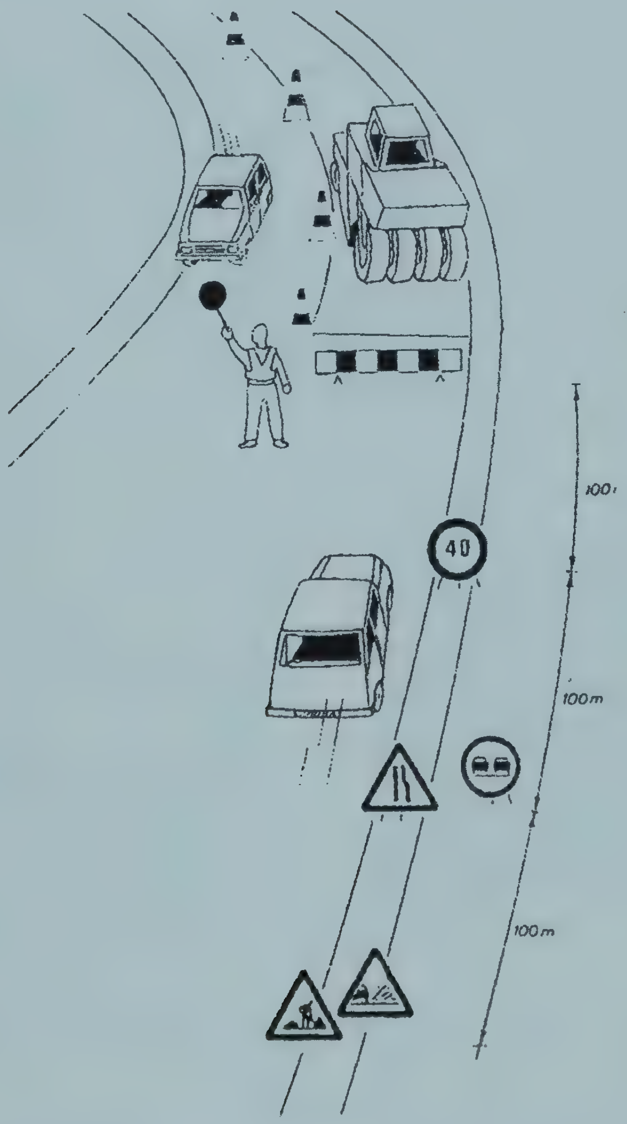


Fig. 8.5. Traffic Control on One-Lane of a Carriageway under Improvement

8.2.3.2. Traffic safety and control : For ensuring safety of workmen and of the travelling public, the work site should be provided with adequate traffic control measures, such as, barricades, cones, signs, markings, lights and flagmen. These devices must be maintained in a satisfactory condition throughout the construction period. It is most important to inspect the traffic arrangements from the point of view of the travelling public and to ensure that, at all times, the public is clearly informed of what it is expected and permitted to do. Some of the safety devices for the workmen are shown in Fig. 8.6.

8.2.3.3. Traffic management during execution : The Ministry of Road Transport and Highways have, from time to time, issued several important circulars for traffic management during execution both from the point of

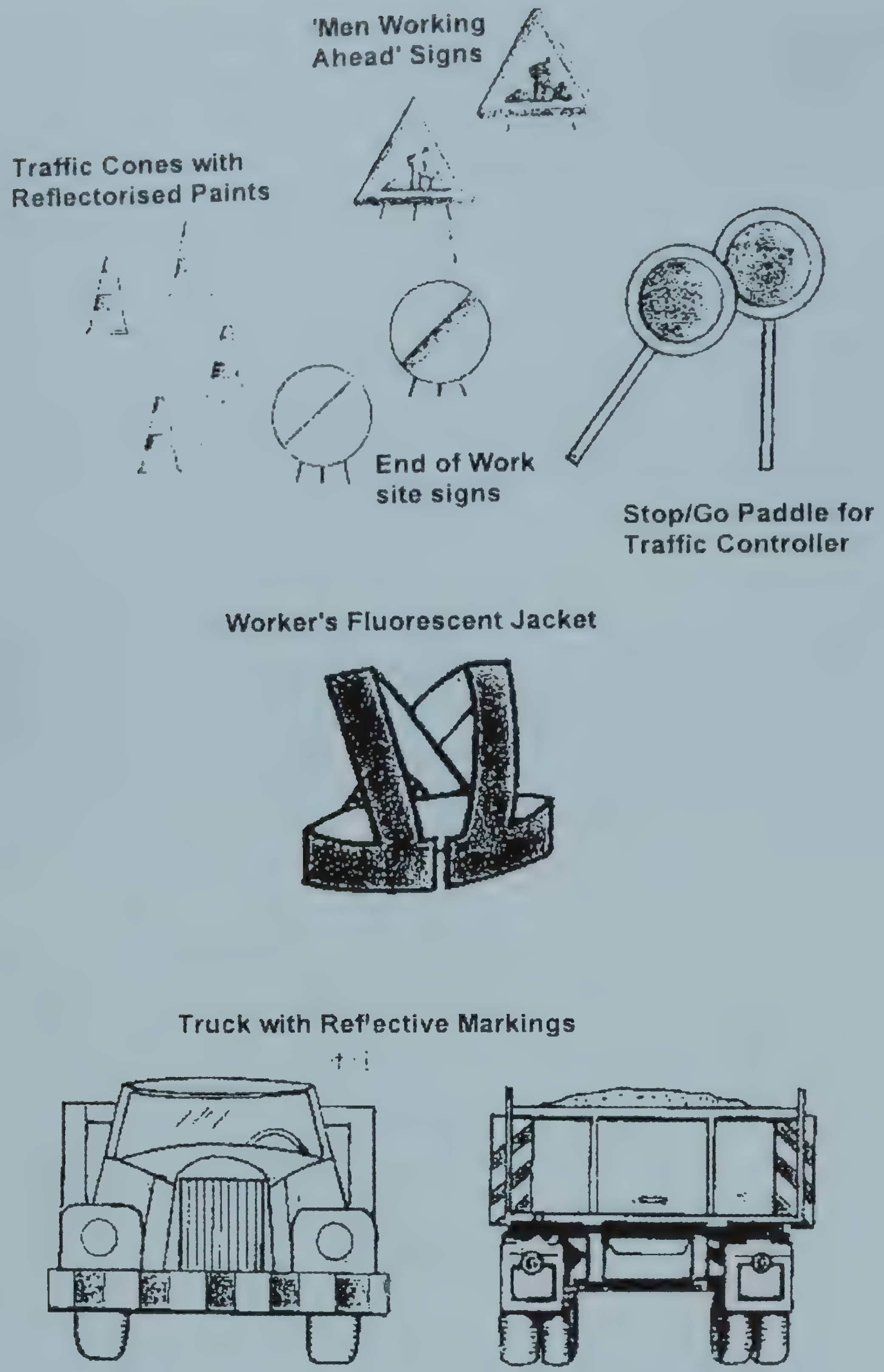

'Men Working Ahead' Signs
Traffic Cones with Reflectorised Paints
End of Work site signs
Stop/Go Paddle for Traffic Controller
Worker's Fluorescent Jacket
Truck with Ref'ective Markings

Fig. 8.6. Some Safety Devices for the Workmen

view of safety as well as facility of road users. As per the Ministry's instructions, typical arrangements to be made for traffic when a section of a National Highway is to be closed due to breach or damage are given in Fig. 8.6 (a). Also, typical arrangements to be made during reconstruction of cross-drainage structure, where traffic may be passed over part width of the structure are given in Fig. 8.6 (b) and wherie traffic may be passed over a temporary diversion, are given in Fig. 8.6 (c). The Indian Roads Congress have recently drafted Guidelines on Safety in Road Construction Zones. The "General Precautions" contained in the above document are reproduced below:

General Precautions

The following defined precautions should apply to all the work sites :

(i) All the signs and delineators should be maintained in a clean and brightly painted condition at all times. There should be a penalty clause in the Contract when the Contractor does not achieve agreed levels of maintenance and cleanliness of signs, markings, delineators, etc.

(ii) Adequate lighting arrangements should be made for proper visibility during the negotiation of the work area especially when it is dark; and

(iii) Adequate arrangements like frequent sprinkling of water should be made to keep the area dust free.

For high traffic density roads, the following further precautions must be taken:

A. For Safety of Workmen

1. Workmen must be trained in use of tools and plant;
2. Gum boots, spectacles, etc. must be given to persons handling bitumen;
3. First-aid training must be given to all workmen and enough safety kits should be available at the sit; and
4. Workers required on site during night hours must be provided with fluorescent yellow jackets with reflective tapes.

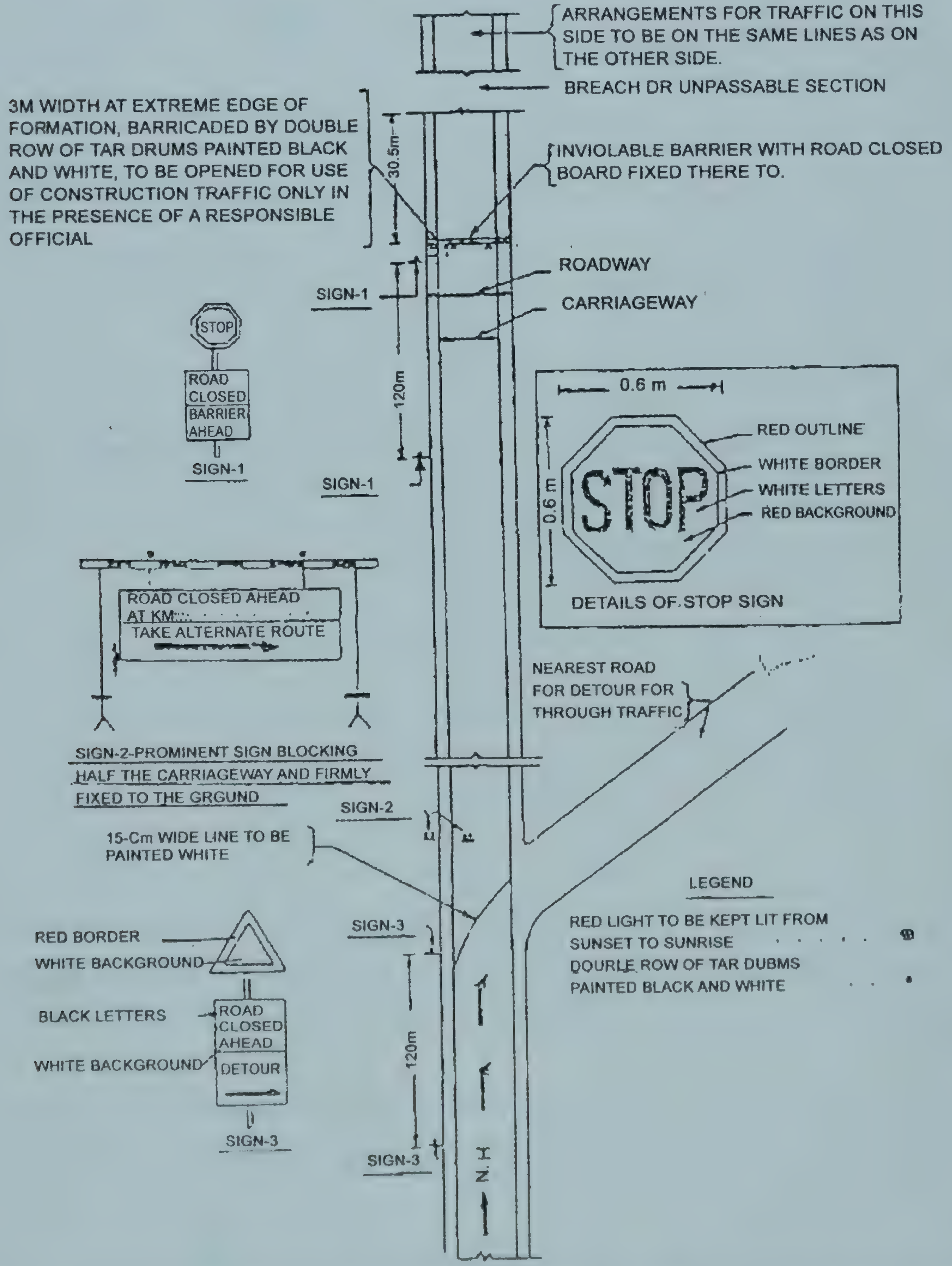

ARRANGEMENTS FOR TRAFFIC ON THIS SIDE TO BE ON THE SAME LINES AS ON THE OTHER SIDE.
BREACH DR UNPASSABLE SECTION
3M WIDTH AT EXTREME EDGE OF FORMATION, BARRICADED BY DOUBLE ROW OF TAR DRUMS PAINTED BLACK AND WHITE, TO BE OPENED FOR USE OF CONSTRUCTION TRAFFIC ONLY IN THE PRESENCE OF A RESPONSIBLE OFFICIAL
30.5m
INVIOLABLE BARRIER WITH ROAD CLOSED BOARD FIXED THERE TO.
ROADWAY
CARRIAGEWAY
SIGN-1
STOP
ROAD CLOSED BARRIER AHEAD
SIGN-1
120m
SIGN-1
0.6 m
0.6 m
STOP
RED OUTLINE
WHITE BORDER
WHITE LETTERS
RED BACKGROUND
DETAILS OF STOP SIGN
ROAD CLOSED AHEAD AT KM.........
TAKE ALTERNATE ROUTE
NEAREST ROAD FOR DETOUR FOR THROUGH TRAFFIC
SIGN-2-PROMINENT SIGN BLOCKING HALF THE CARRIAGEWAY AND FIRMLY FIXED TO THE GRGUND
SIGN-2
15-Cm WIDE LINE TO BE PAINTED WHITE
LEGEND
RED LIGHT TO BE KEPT LIT FROM SUNSET TO SUNRISE
DOURLE ROW OF TAR DUBMS PAINTED BLACK AND WHITE
RED BORDER
WHITE BACKGROUND
BLACK LETTERS
WHITE BACKGROUND
ROAD CLOSED AHEAD
DETOUR
SIGN-3
SIGN-3
120m
SIGN-3
N.H

Fig. 8.6(a). Arrangements for Traffic when a Section of National Highway is to be closed due to Breach or Damage (as per Ministry of Road Transport and Highways)

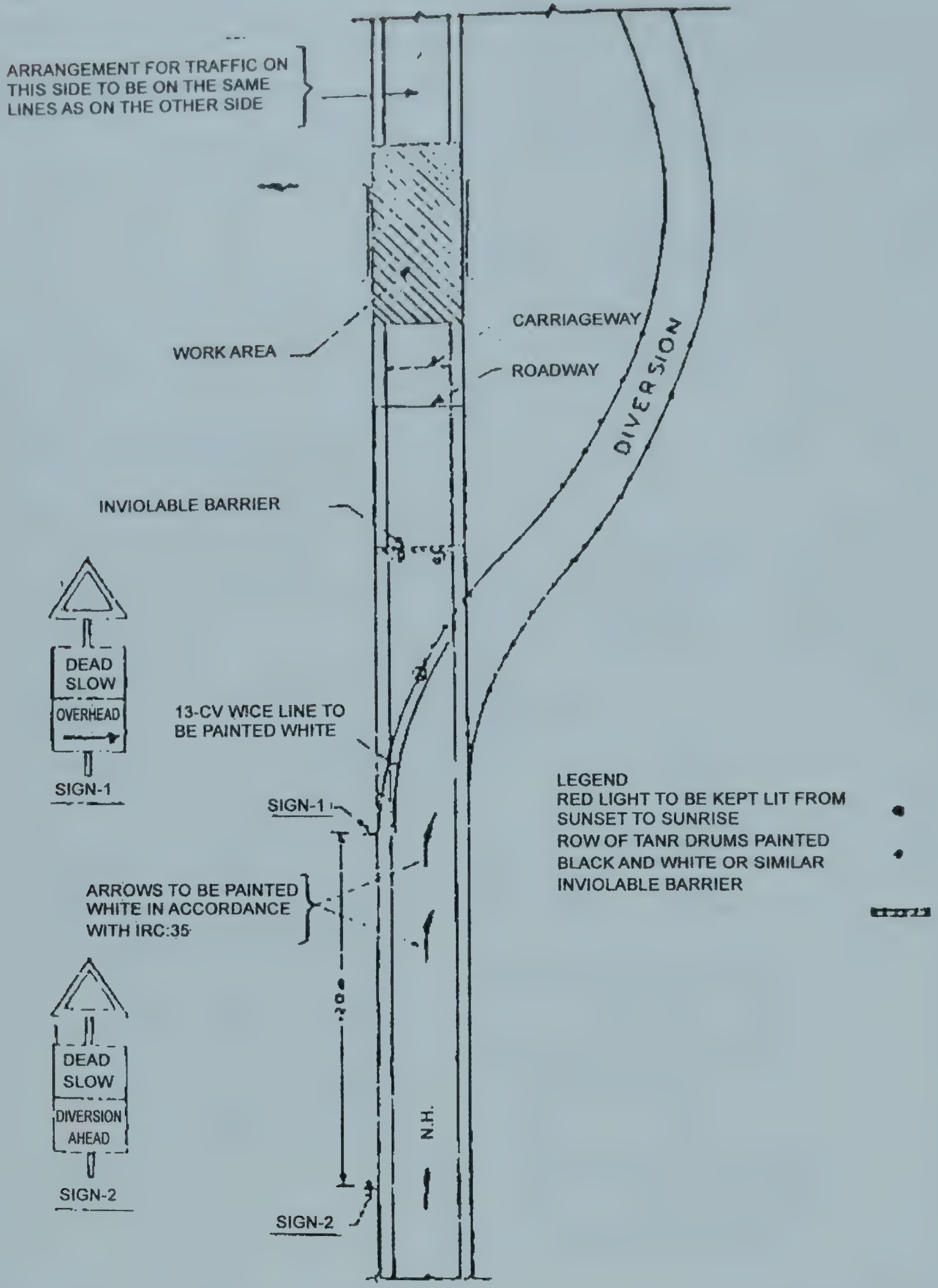

ARRANGEMENT FOR TRAFFIC ON THIS SIDE TO BE ON THE SAME LINES AS ON THE OTHER SIDE
WORK AREA
CARRIAGEWAY
ROADWAY
DIVERSION
INVIOLABLE BARRIER
DEAD SLOW
OVERHEAD
SIGN-1
13-CV WICE LINE TO BE PAINTED WHITE
SIGN-1
ARROWS TO BE PAINTED WHITE IN ACCORDANCE WITH IRC:35
DEAD SLOW
DIVERSION AHEAD
SIGN-2
SIGN-2
N.H.
LEGEND
RED LIGHT TO BE KEPT LIT FROM SUNSET TO SUNRISE
ROW OF TANR DRUMS PAINTED BLACK AND WHITE OR SIMILAR
INVIOLABLE BARRIER

Fig. 8.6(b). Arrangements during Reconstruction of Cross-Drainage Structures where Traffic can pass over part width of the Structure (as per Ministry of Road Transport and Highways)

B. For Safety of Road User

1. As far as possible, the material, equipment and machinery should be stacked/installed/parked in places sufficiently away from the road berms in available road land. Only in unavoidable cases should they be allowed near the edge of the berms, but never on berms near and on curves;

2. Machinery should be parked at appropriate places with red flags and red lights on; and

3. Only the minimum quantity of material required for one operation should be stacked as above.

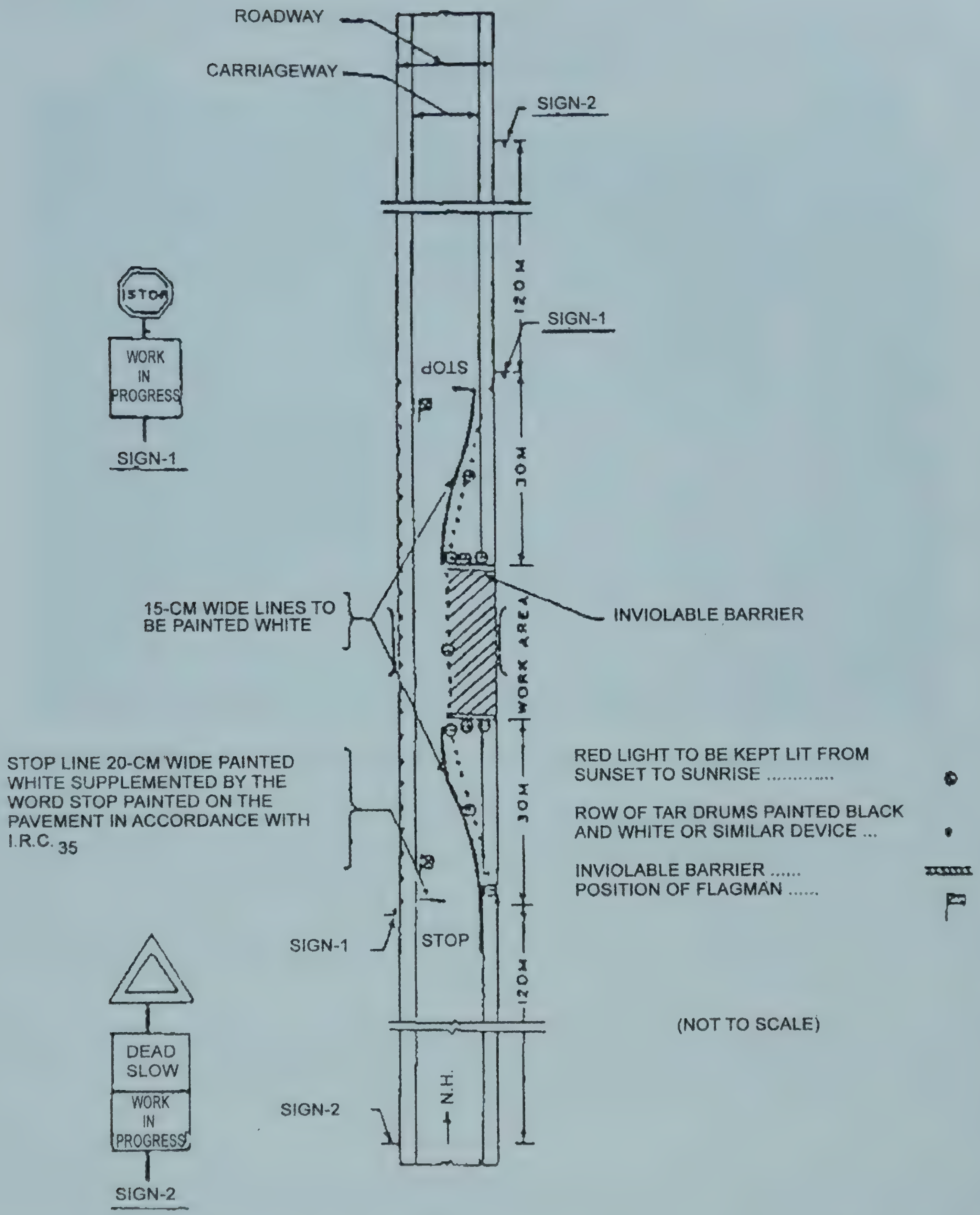

ROADWAY
CARRIAGEWAY
SIGN-2
120 M
SIGN-1
STOP
WORK
IN
PROGRESS
SIGN-1
STOP
30 M
15-CM WIDE LINES TO BE PAINTED WHITE
INVIOLABLE BARRIER
WORK AREA
STOP LINE 20-CM WIDE PAINTED WHITE SUPPLEMENTED BY THE WORD STOP PAINTED ON THE PAVEMENT IN ACCORDANCE WITH I.R.C. 35
RED LIGHT TO BE KEPT LIT FROM SUNSET TO SUNRISE ....
ROW OF TAR DRUMS PAINTED BLACK AND WHITE OR SIMILAR DEVICE ...
INVIOLABLE BARRIER ......
POSITION OF FLAGMAN ......
30 M
SIGN-1
STOP
120 M
(NOT TO SCALE)
DEAD
SLOW
WORK
IN
PROGRESS
SIGN-2
N.H.
SIGN-2

Fig. 8.6(c). Arrangements during Reconstruction of Cross-Drainage Structures where Traffic can pass over a Diversion (as per Ministry of Road Transport and Highways)

8.2.4. Preparation of surface

8.2.4.1. Preliminary operations : Before any new construction can be laid, the condition of the surface should be carefully inspected and measures taken to prevent re-appearance of deficiencies on the newly laid courses.

If the existing surface is granular, it may be necessary to scarify, reshape or recompact the top layer or place additional fresh material where required. All loose, disintegrated and extraneous matter must be removed by means of a mechanical broom or any other approved equipment/method. The use of an air jet from a compressor (Fig. 8.7) to blow away dust or loose matter should be specified where appropriate. Any settlement in fills near approaches to structures, r\itting along wheel paths, etc. should be repaired.

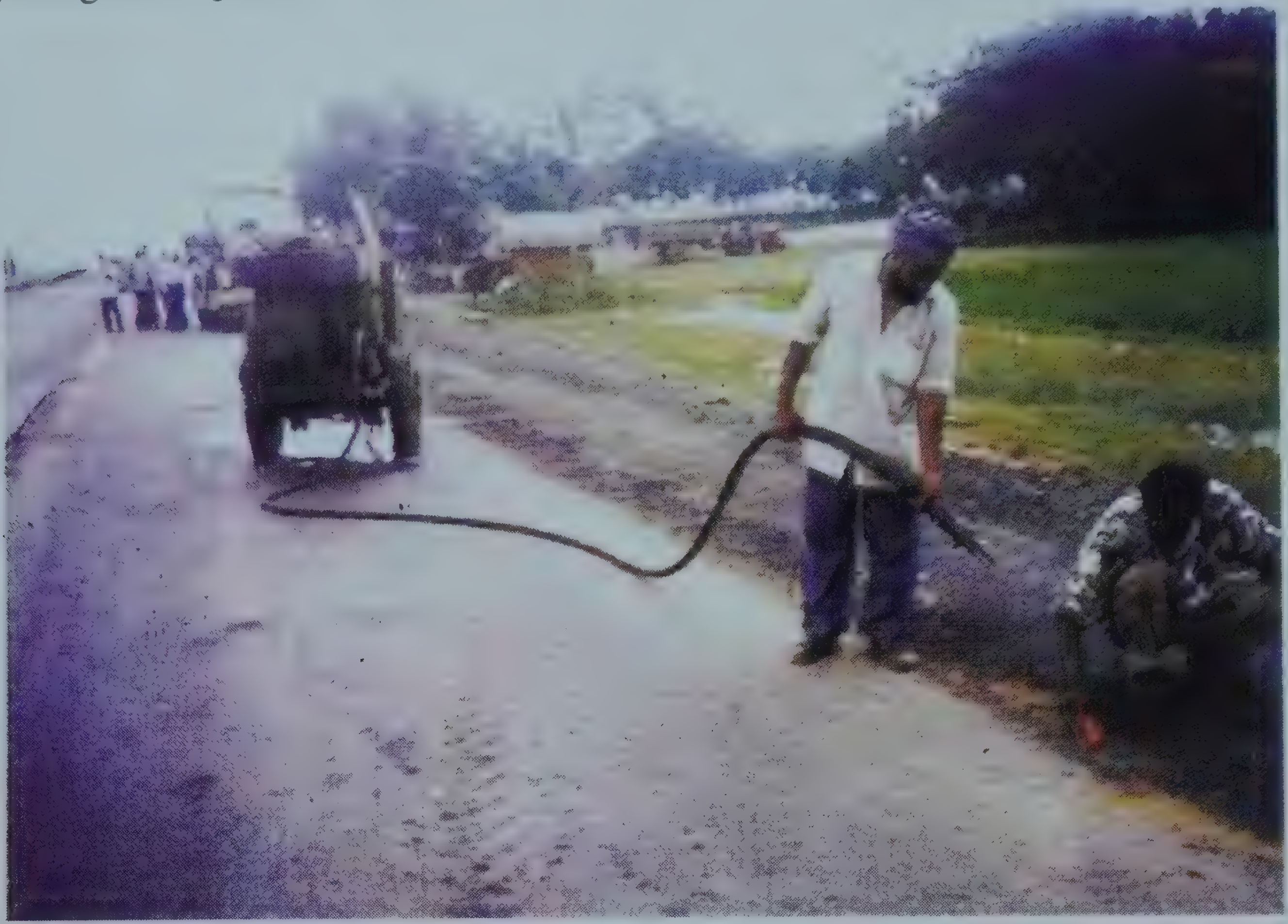


Fig. 8.7. Air Jet from a Compressor used to blow away Dust/Loose Aggregates

On new roads, it is of prime importance that the granular layer after formation has the correct grade and crown. Curves should be provided with the design superelevation right from the subgrade and granular base course layers. Priming of granular surface should be carried out before laying of the bituminous layer.

A cold joint should be carefully trimmed with a jack hammer (Fig. 8.8) or any other suitable cutting device before placing hot material in the adjoining lane.

Any damage on existing bituminous surfaces like cracks, shallow ,depressions, ruts, corrugations, shoving and potholes should be repaired as outlined in subparas (a) to (f) below :

(a) Cracks

(i) **Crack Sealing :** For areas having cracks with less than 3 mm width, treatment by fog spraying conforming to the requirements of Clause 518 of revised Ministry's Specifications (2001) should be considered.

The area to be treated with fog seal should be thoroughly cleaned using compressed air, scrubbers, etc., the cracks should be cleaned with a compressed air jet to remove all dirt, dust, etc. The fog seal should be applied at the rate of 0.5-1.0 litre/sqm of slow setting emulsion, using equipment, such as, a pressure tank, flexible hose and spraying bar or lance. Traffic should be allowed on to the surface only after the seal has set to a non-tacky and firm condition so that it is not picked up by the tyres.

If cracking above 3 mm in width is widely present, surface dressing, after sealing the wider (6 to 15 mm) cracks, will provide a good seal for the 3 to 6 mm cracks which are too small and often too numerous to be sealed individually.

(ii) **Crack Filling :** Crack filling should be carried out using a binder of a suitable viscosity, normally a slow setting bitumen emulsion. For wider cracks, in excess of an average of 8 mm in width, the application of emulsion may be preceded by an application of crusher dust, or other fine material, passing the 4.75 mm sieve but with maximum of 10 per cent passing the 0.075 mm sieve.

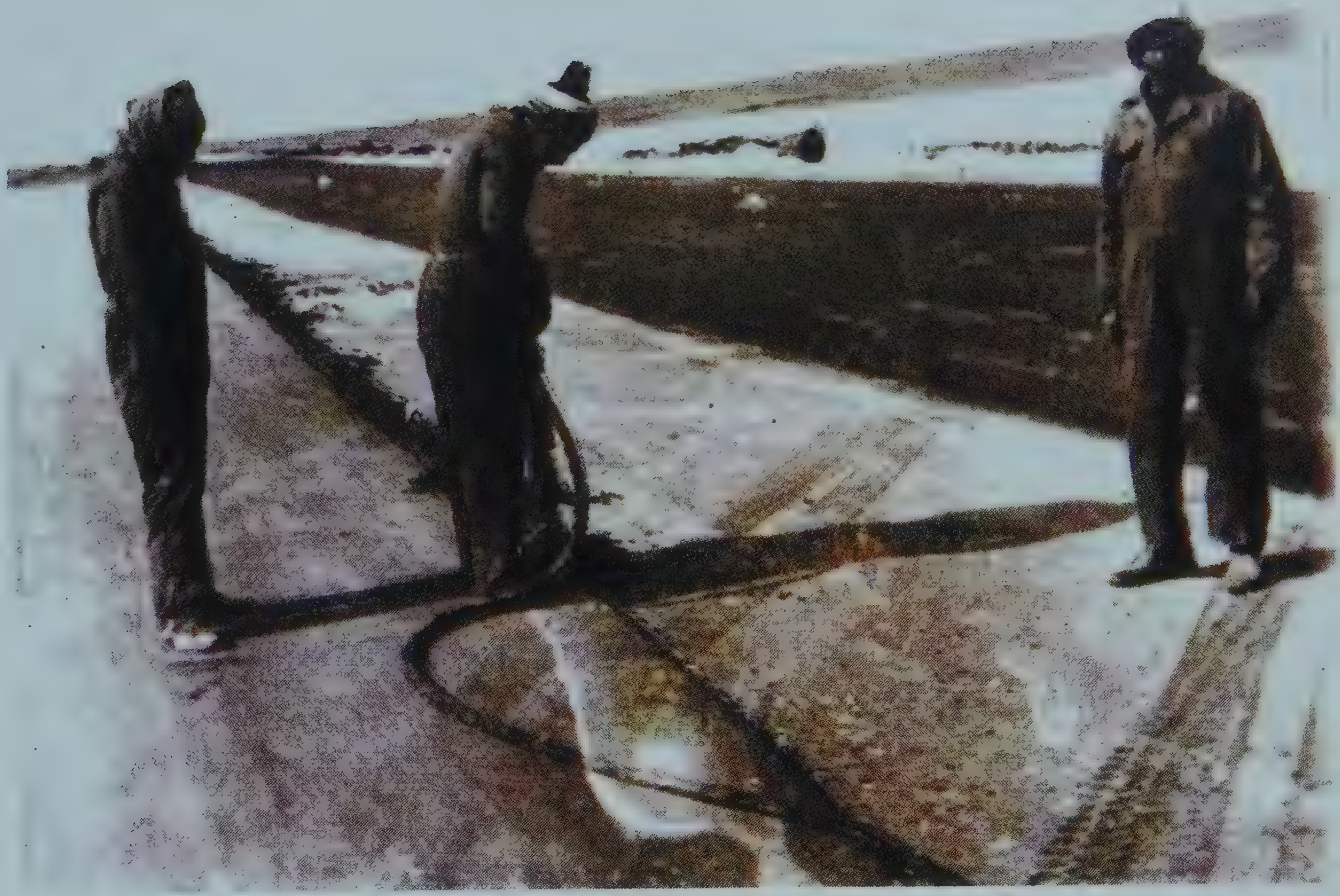


Fig. 8.8. Cold Longitudinal Joint being cut with a Jack-Hammer before placing adjoining Bituminous Layer

If dust is to be used it should be placed in the cracks before the application of binder and filled to a level approximately 5mm below road surface level. The surface of the road should be swept clear of dust prior to the application of binder. Binder should be poured into the cracks, taking care to minimise spillage.

If spillage onto the road surface does occur, dust should be applied to the excess bitumen until it is blotted up.

For cracks between 6 and 15mm, a premixed sand asphalt is a good crack filler. This can be mixed by hand, on site, with straight run, cutback or emulsified bitumen. The cracks should be blown out, sides painted with bitumen, and sand asphalt, hand or mechanically compacted, placed in the crack.

(iii) **Crack Prevention Courses :** Two of the measures that can be adopted to prevent the propagation of cracks are the provision of Stress Absorbing Membrane (SAM) and Stress Absorbing Membrane Interlayer (SAMI). Details of these two measures are given in para 9.7.6.9 of this Manual and Clause 522 of the revised Ministry's Specifications.

(b) **Shallow Depressions**

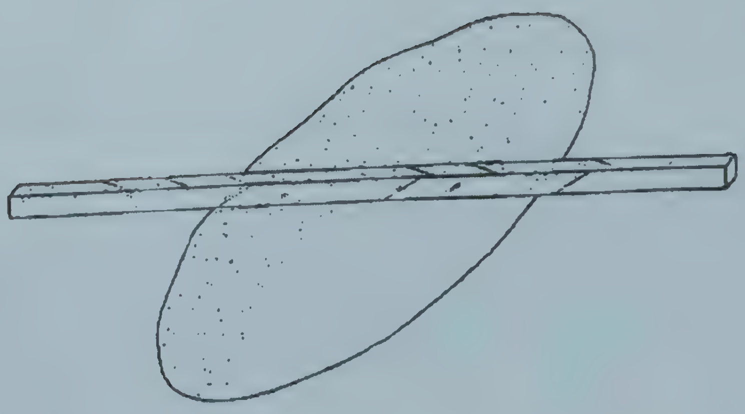
Shallow depressions which are essentially localised low-areas, about 25 mm or more below the desired profile are made up by filling with premix materials, open-graded or dense-graded and compacting to the desired profile as the surrounding pavement. A step-wise procedure for filling in depressions is given Fig. 8.9 (a) to (e).

(c) **Ruts**

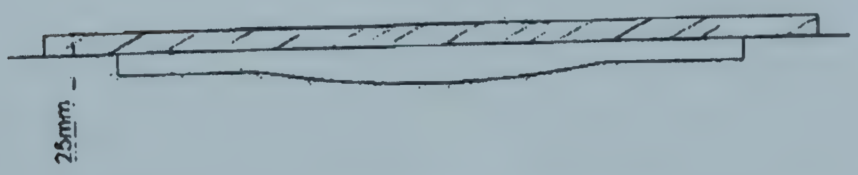
Ruts are basically grooves or longitudinal depressions in the wheel tracks. Their rectification consists of filling up with bituminous premix, open-graded or dense-graded patching materials and compacting to the desired levels. The limits of the depression are first determined with a string line and marked on the surface. After applying a suitable tack coat, the premix is spread and compacted. Situations indicative of shear failure or subgrade movement, however, generally require reconstruction.

(d) **Shoving**

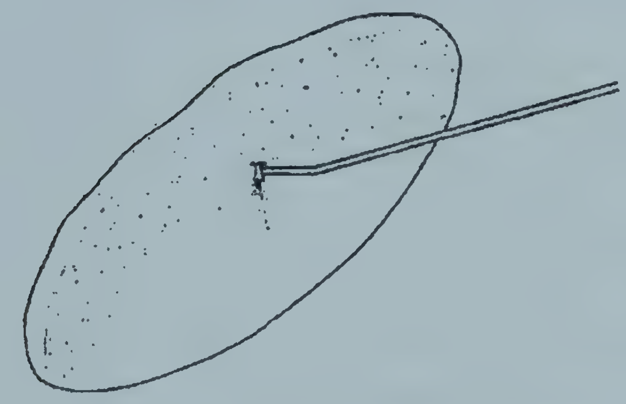
The rectification consists of removing the material in the affected area down to a firm base and laying a stable premix patch.



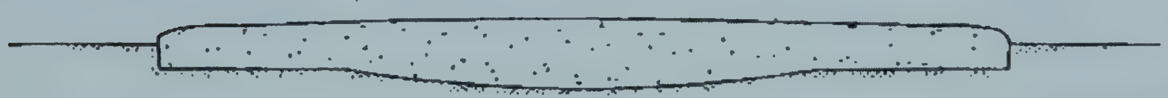
(a). MARK THE DEPRESSED AREA TO BE CORRECTED USING A STRAIGHT EDGE. THE OUTLINE TO BE MARKED WITH A CHALK.



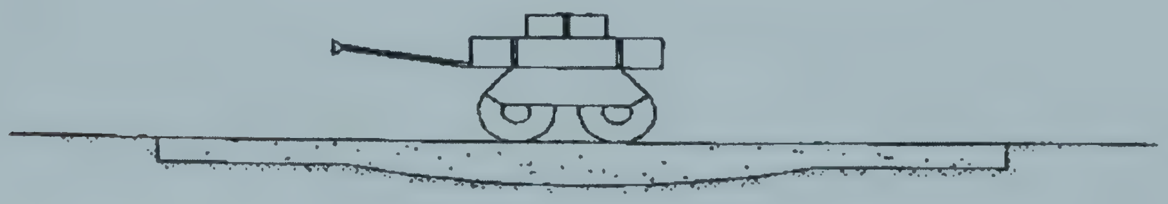
(b). THE EDGES ARE TO BE CUT USING PREFERABLY JACK HAMMER OR PICK-AXE TO A DEPTH OF MINIMUM 25mm AS SHOWN IN THE SKETCH (b)



(c). SPRAY TACK COAT USING SPRAY LANCE OR PERFORATED CAN. TO A DEPTH OF MINIMUM 25mm AS SHOWN IN THE SKETCH (b)



(d). FILL THE DEPRESSION WITH THE BITUMINOUS MIX LEAVING AN EXCESS THICKNESS (SURCHARGE) OF ABOUT ONE THIRD THE DEPTH OF THE DEPRESSION TO ALLOW FOR COMPACTION.



(e). THE MIX IS COMPACTED USING A SMALL VIBRATING ROLLER OR A RAMMER UNTIL THE SURFACE IS LEVEL.

Fig. 8.9. Filling in Depressions

(e) **Corrugations**

These are essentially ripples or regular undulations across a bituminous surface, usually shallow, of the order of 25 mm in depth, with about 3 m spacing. If the surface is thin, it is scarified, including some portions of the underlying base and the scarified material is recompacted. A new surfacing layer is then laid. The cutting of high spots with or without heating, and addition of levelling course materials can also be resorted to. Spreading of sand bituminous premix with a drag spreader with its blade adjusted to just clear the high spots can also be an effective way to make-up the corrugations. The area is then thoroughly rolled.

(f) **Potholes**

These bowl-shaped holes of varying sizes are a common type of distress. The filling of potholes and patch repairs can be carried out as under :

Each pothole and patch repair area should be inspected and all loose material removed. The area should be cut/ trimmed either with jack hammers or with hand tools suitable for the purpose, such that any loose material is removed and such that the excavation is of a reasonably regular shape.

The edges of the excavation should be cut vertically where possible, but care should be taken not to disturb any large or tightly held stone in the base layer. The area should be thoroughly cleaned with preferably a compressed air high pressure jet, or other appropriate method to remove all dust and loose particles. Layers below the level of the bituminous construction should be replaced using material of the equivalent specification to the original construction. The area for bituminous construction should be primed with pre-heated penetration grade bitumen, or cutback or emulsion depending upon whether the lower area is bituminous or granular in nature. The sides, however, are to be painted with hot prime coat material using a brush. The prime coat should conform to para 8.3.1.

The mixture to be used in bituminous patching can be either a hot mix or a cold mix. Mixing should be done in a plant of suitable capacity. The bituminous mixture should be placed in layers of thickness not more then 100 mm (loose) and should be compacted in layers with roller/plate compactor/hand roller/hand rammer, to the desired compaction standards. While placing the final layer, the mix must be spread slightly proud of the surface so that after rolling, the surfaced should be flush with the adjoining surface. If the area is large, the spreading and levelling should be done using hand shovels and wooden straight edges. During the process of compaction, the surface should be Checked using a 3 m straight edge.

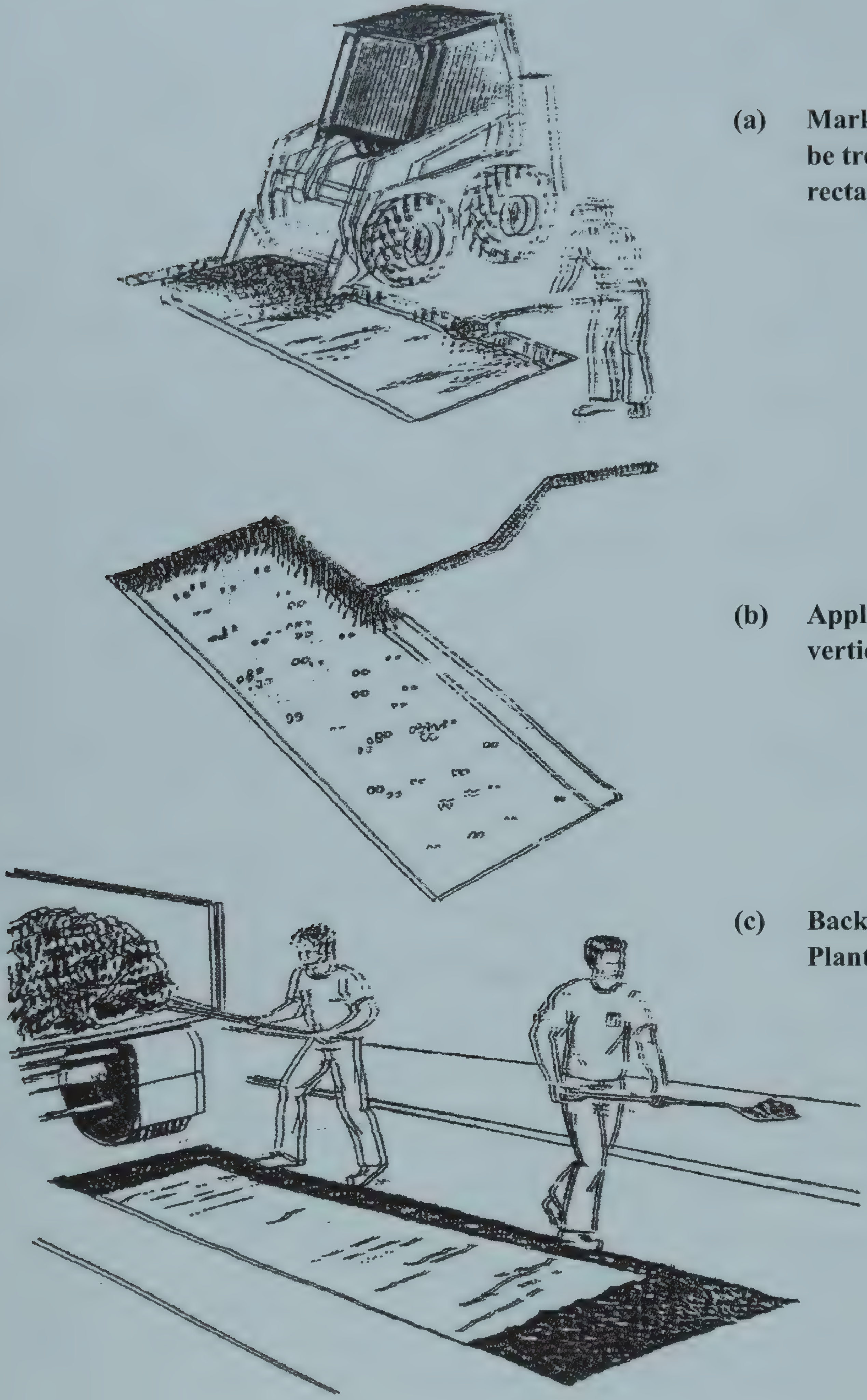
A successful and very simple technique for patching of potholes Frequently used in India, particularly on more lightly trafficked roads, which is that of penetration macadam. This technique involves cleaning the pothole as described above, priming the cleaned surface with pre-heated penetration grade bitumen, and filling the hole with dry clean aggregate, which is then sprayed with the pre-heated bitumen, sufficient to penetrate the dry aggregate. The aggregate should be single sized, to enable penetration. 10 mm size stone is used for small shallow holes, and larger stone say 25 mm used for larger holes, where it is blinded with the smaller stone before application of bitumen. This technique requires simple tools, is usually carried out by hand, and is very cost effective.

The various steps involved in filling-up a pothole with a pre-mixed bituminous mixture are shown in Figs. 8.10(a) to (f).

Where a pothole has gone deep into the granular base course, a simple step-wise procedure for filling it up with the use of only very simple tools is shown in Fig. 8.11. It may, however, be noted that this simple procedure is applicable only to roads with a thin bituminous surface treatment, like, surface dressing or thin premix carpet.

8.2.4.2. Profile correction course : Most bituminous overlay works require the construction of a profile correction course in order to correct the camber of the existing surface and rectify local irregularities in the longitudinal profile. The profile correction course may be laid as part of the overlay/strengthening course,or as a separate layer. In the former case, the material for the profile correction course should be the same as that of the overlay/strengthening course. If it is laid as a separate layer, it must have a specification at least the equivalent of the layer over which it is to be laid.

The ideal method for determination of profile corrective course requirement is by plotting the cross-sections of the existing road surface, then running a design longitudinal grade line through them and fixing the new crown points and edge points with respect to the existing cross-sections. The required quantities of cutting and filling can, thus, be calculated.

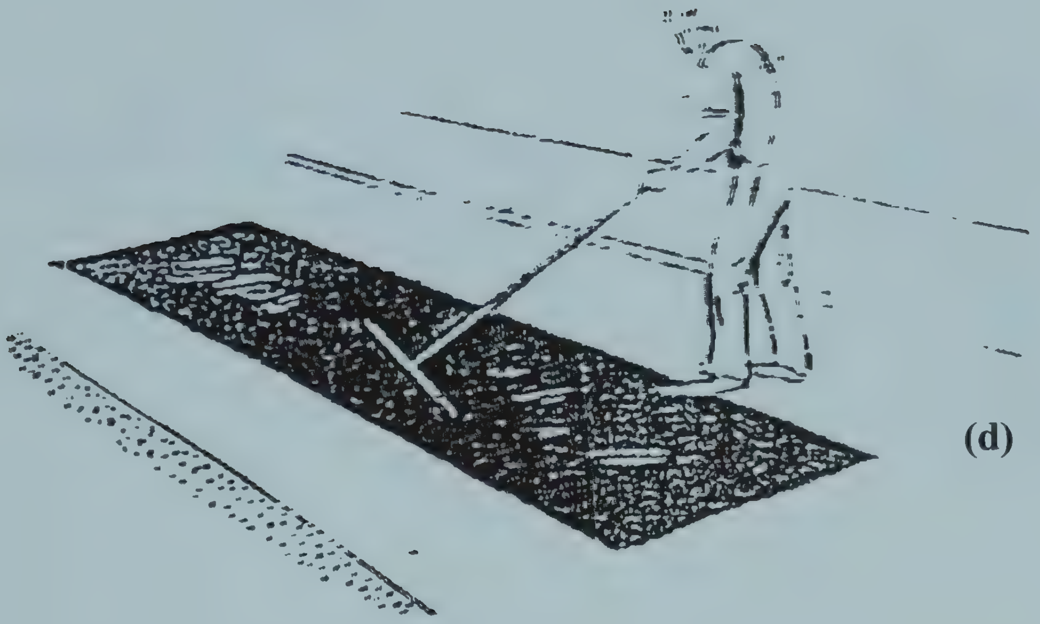


(a) Mark the area to be treated and cut rectangular in shape

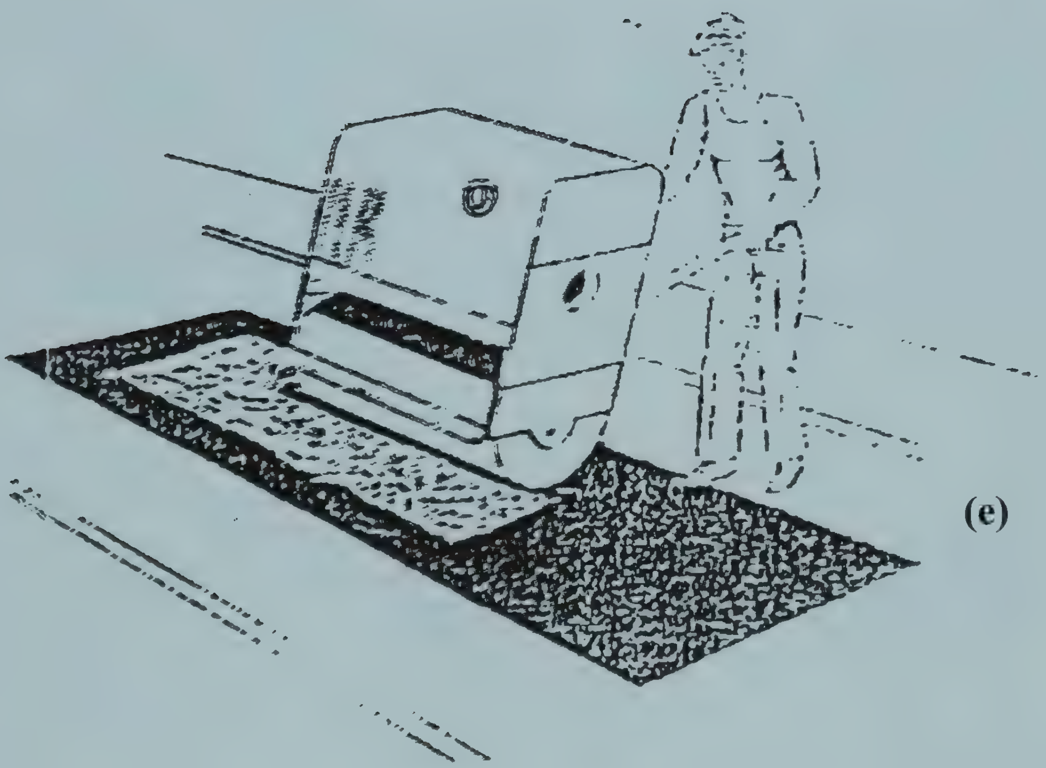
(b) Apply a tack coat on vertical faces

(c) Backfill the hole with Plant Mix

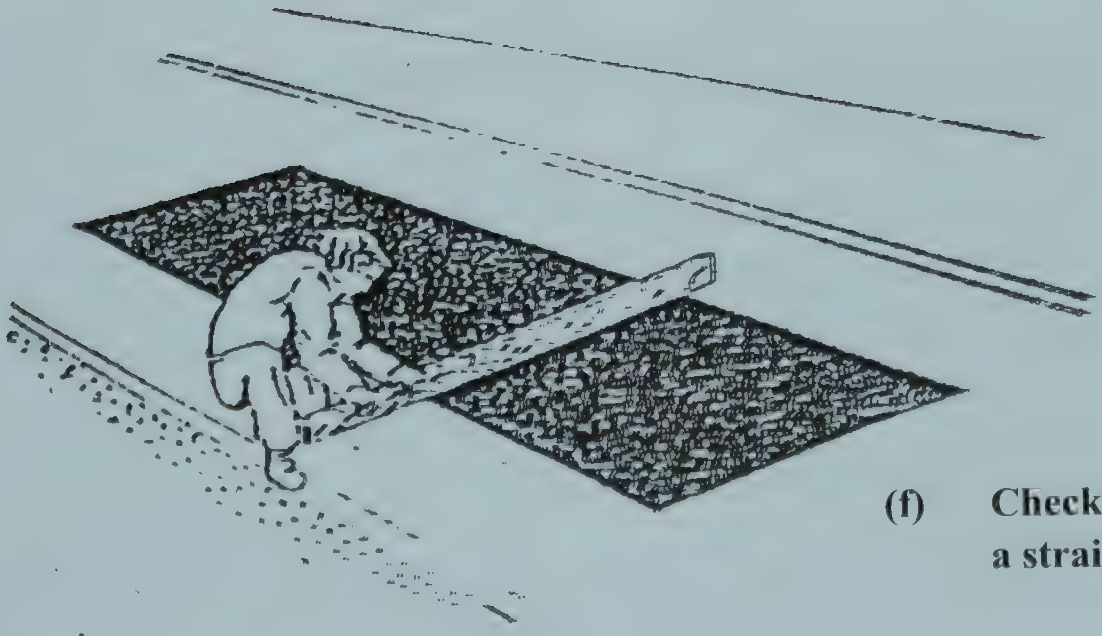
Fig. 8.10. Filling a Pothole



(d) Spread the Mix

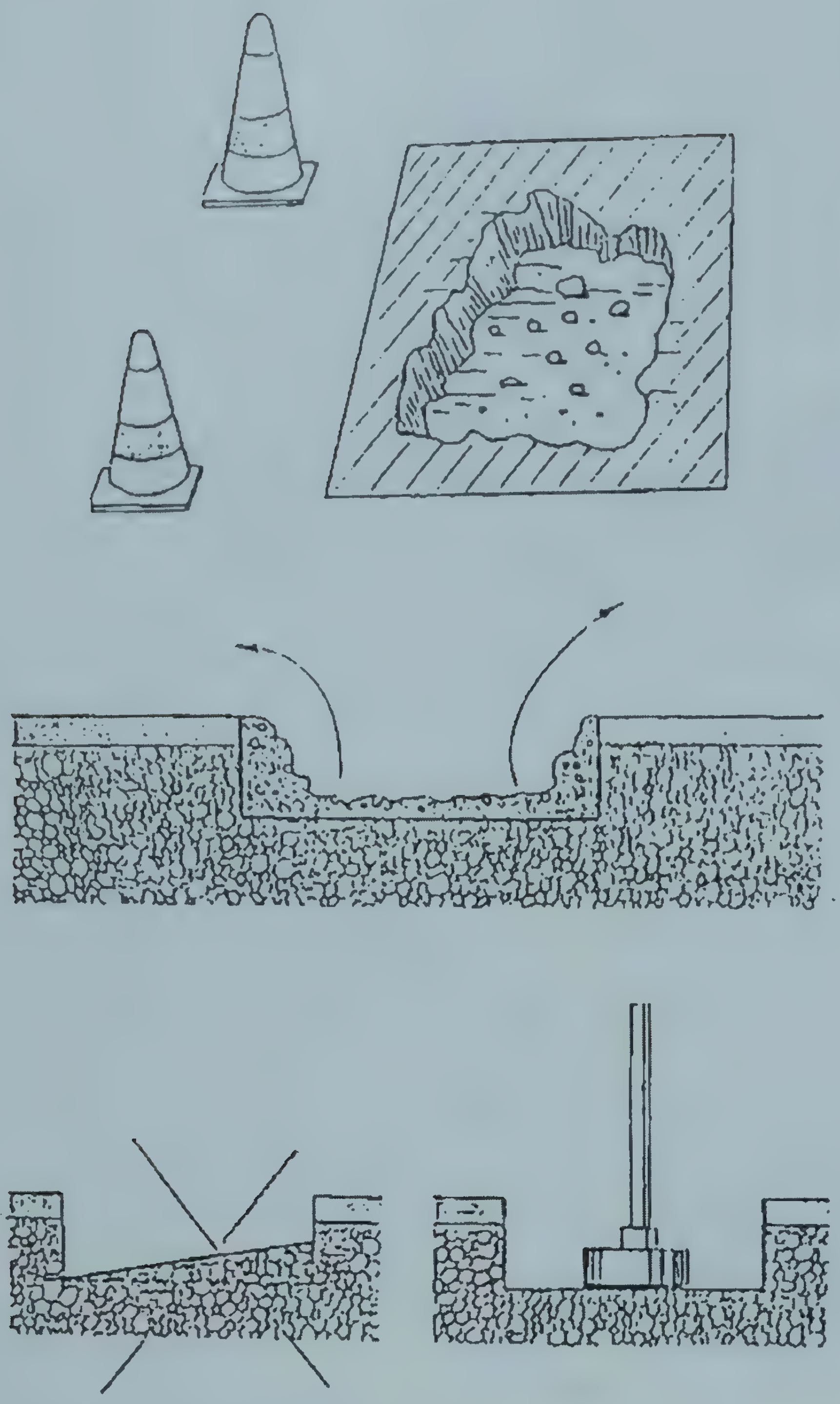


(e) Compact the Mix



(f) Check the patchod surface with a straightedge

Fig. 8.10. (Contd.) Filling a Pothole



Mark out the area to be repaired and remove all material from within the marked-out area

Increase the depth of the hole until firm material is found; walls of hole should be made vertical

Dress the bottom of the hole such that it is flat and horizontal; then compact it.

Fig. 8.11. Patching

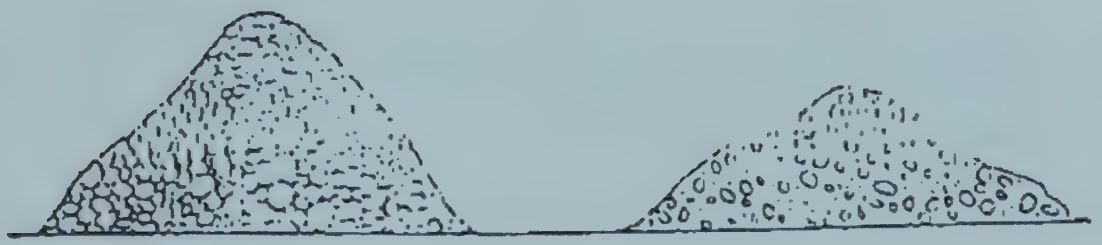
In certain situations of local distortion, hump or undulations over limited areas, the establishment of the design grade line may need milling, cold planing or hot planing.

Unbroken sags or depressions may be set right by placing a number of layers of levelling course. The (correct and incorrect procedures are shown in Fig 8.12. The maximum layer thickness at any point should be 100 mm.

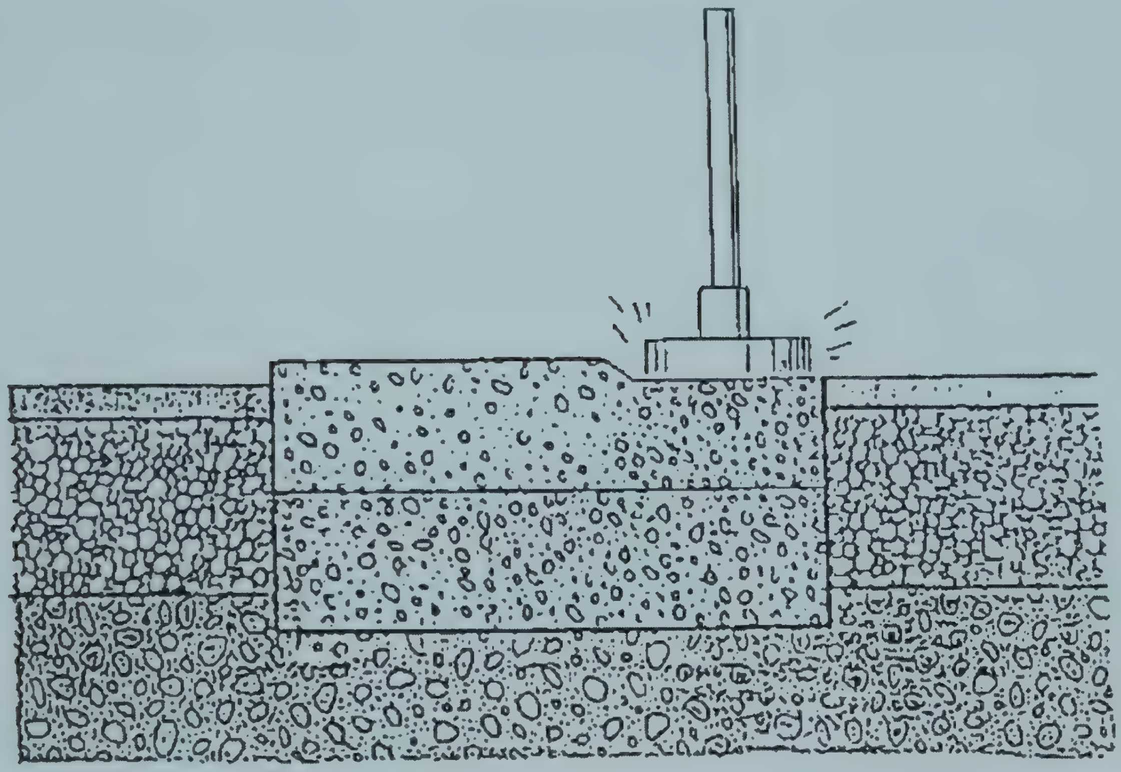
This procedure eliminates formation of multiple joints at the top and the possibility of bump formation by squeezing of materials from the lower layers.

The correction of camber should be carried out as shown in Fig. 8.13.

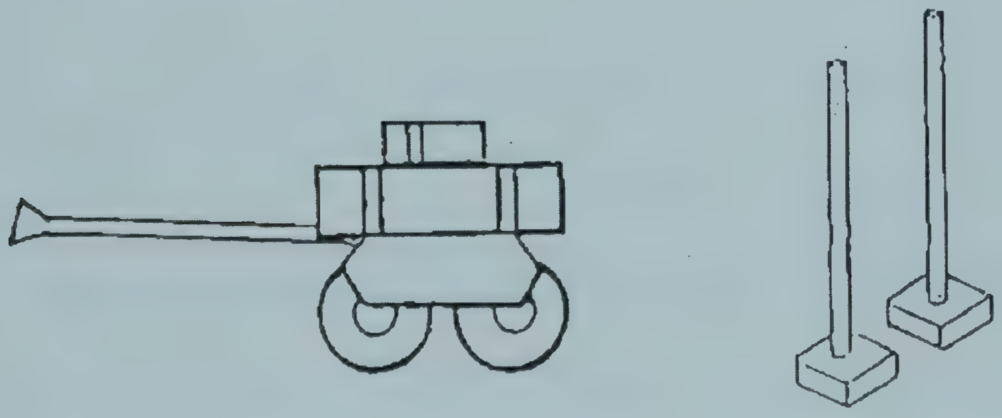
A tack coat is generally needed prior to laying of the profile corrective course, and, when laid, the profile correction should be trimmed to the correct levels and thoroughly compacted.



Backfill the hole with
(i) a material of the same quality as that of the base layer
(ii) or a cold mix



Compact in one or more layers of regular thickness depending on depth. Last layer to have excess thickness of 1/5 (depth of excavation)



Compact using a small vibratory roller or hammer

Fig. 8.11. (Contd.) Patching

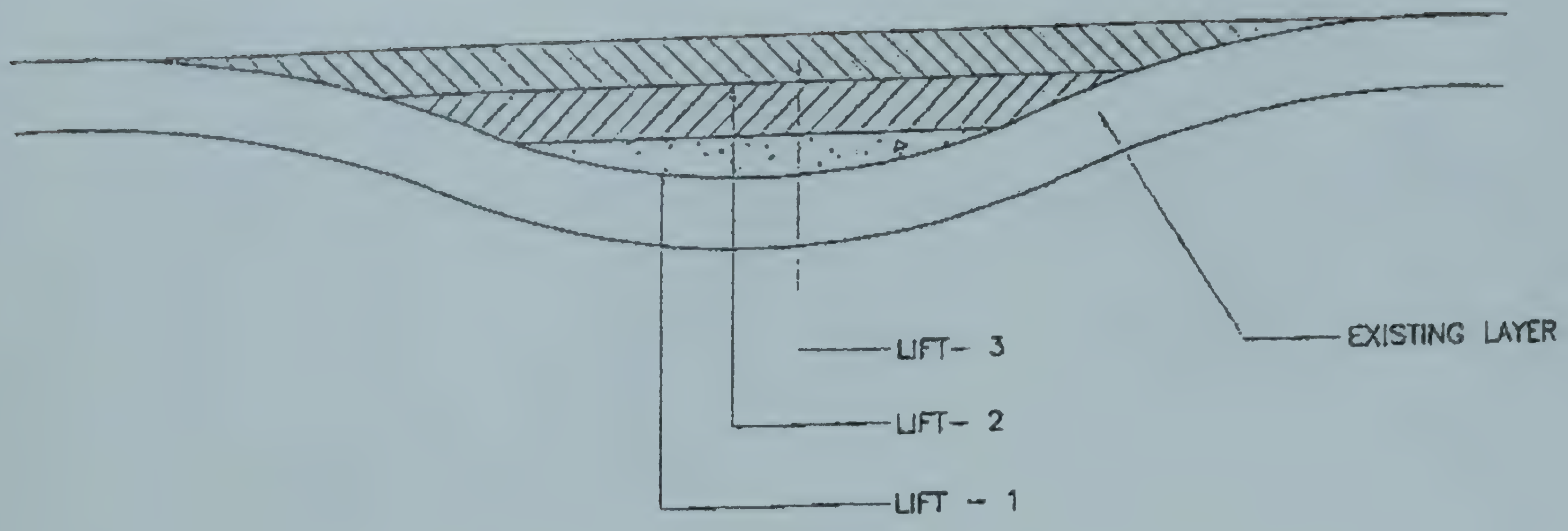
8.3. Sprayed or Penetration Layer Bituminous Construction

In this type of construction, bituminous binder is sprayed on the surface to be treated; bitumen and gregate are not mixed prior to laying, but are placed in separate courses or layers.

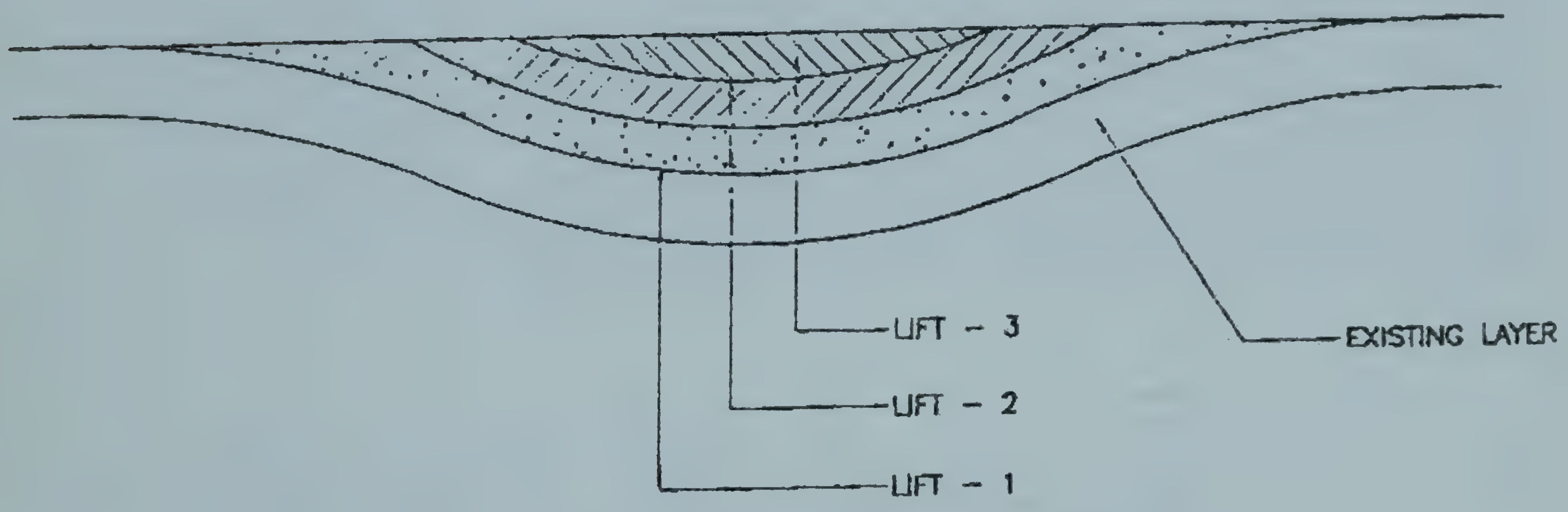
The various requirements for the spraying of liquid bituminous material are given: -

1. Equipment

The success of surface treatments is very much dependent on the binder being applied uniformly at the correct rate of spread and this is governed by the quality, maintenance, calibration and operation of the binder distributor. While some salient features of Bitumen Binder Distributors are described in para 6.3, detailed information is available from the following publications:-



(A) CORRECT METHOD



(B) INCORRECT METHOD

Fig. 8.12. Methods for providing Corrective Course for Short Sags and Depressions

IRC:SP:34-1989, General Guidelines about the Equipment for Bituminous Surface Dressing.

IRC:72-1978, Recommended Practice for Use and Upkeep of Equipment, tools and Appliances for Bituminous Pavement Construction.

The Asphalt Handbook, Manual Series No. 4, 1989.

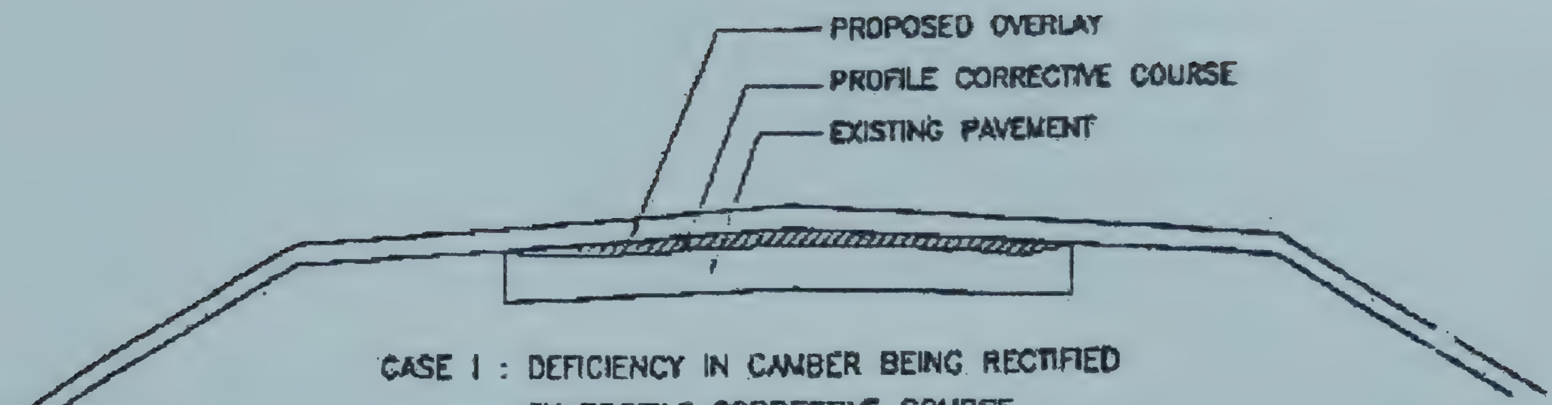
BS:3136, Part 2 : 1972, Specification for Cold Emulsion Spraying Machines for Roads

BS:1707 - 1970, Specification for Hot Binder Distributors for Road Surface Dressing

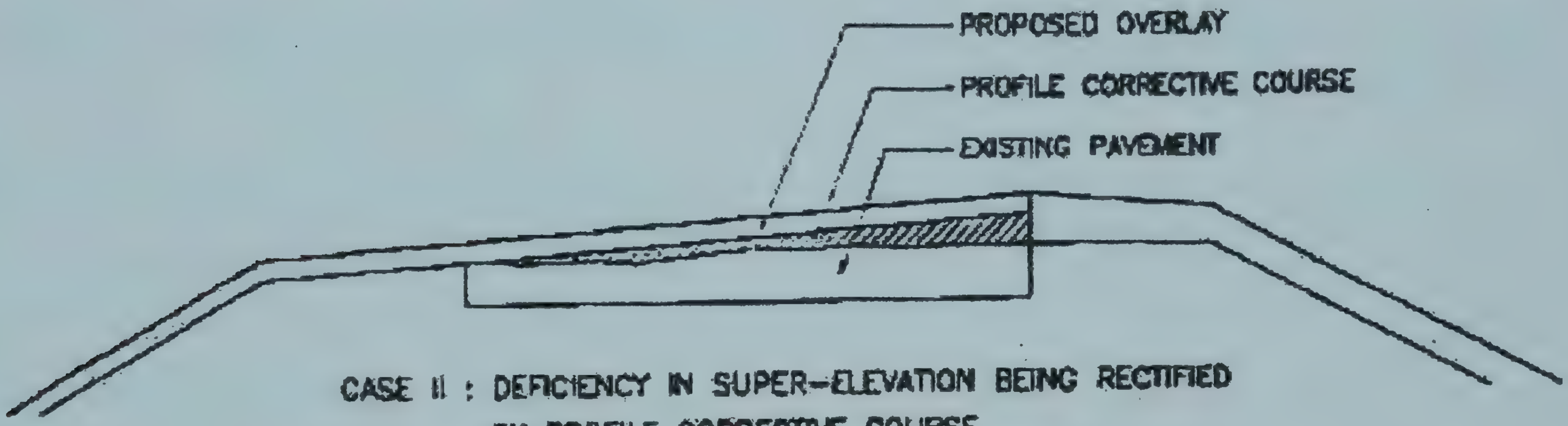
Of the various types of distributors, the constant volume and constant pressure types are commonly used. The distributor used on the contract should comply with all requirements given for their use in IRC:SP-34 and in addition to the following:

(i) All the equipment must be in good working order and kept clean at all times.

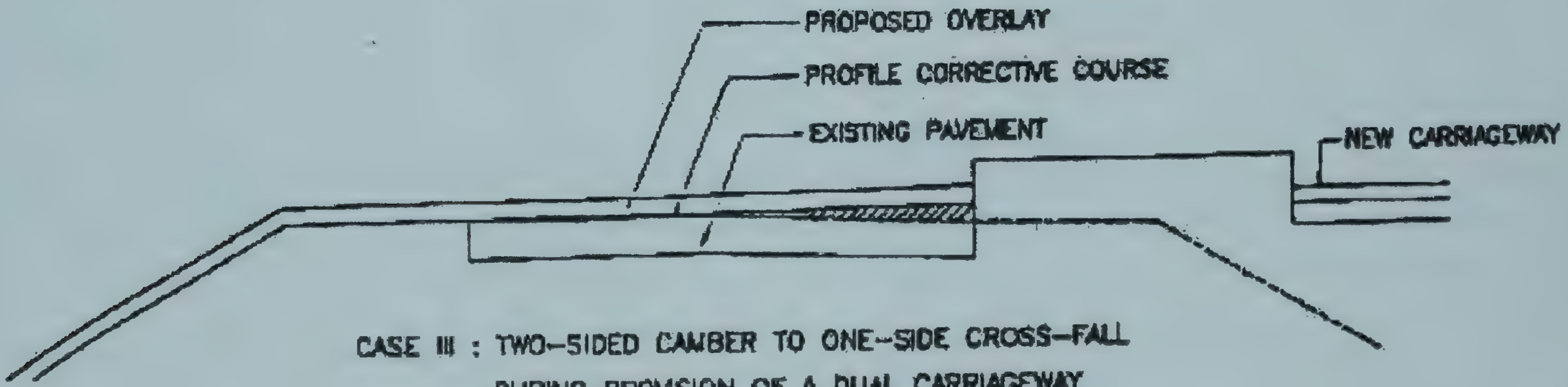
(ii) The uniformity of transverse distribution of a spray bar should be checked at least once a year or more frequently, if required.


PROPOSED OVERLAY
PROFILE CORRECTIVE COURSE
EXISTING PAVEMENT

CASE I : DEFICIENCY IN CAMBER BEING RECTIFIED
BY PROFILE CORRECTIVE COURSE


PROPOSED OVERLAY
PROFILE CORRECTIVE COURSE
EXISTING PAVEMENT

CASE II : DEFICIENCY IN SUPER-ELEVATION BEING RECTIFIED
BY PROFILE CORRECTIVE COURSE


PROPOSED OVERLAY
PROFILE CORRECTIVE COURSE
EXISTING PAVEMENT
NEW CARRIAGEWAY

CASE III : TWO-SIDED CAMBER TO ONE-SIDE CROSS-FALL
DURING PROVISION OF A DUAL CARRIAGEWAY

Fig. 8.13. Correction of Camber or Super-Elevation

8.13. Correction of Camber or Super-Elevation

(iii) The height of the spray bar should be checked and adjusted frequently to give the required overlap (double or triple see IRC:SP:34).

(iv) The distributor must be equipped with .a fifth wheel which operates a low range speedometer in the driver's cab, or other approved system, which enables a steady forward speed to be maintained relatively easily.

(v) The distributor must be properly calibrated and a copy of the calibration chart kept in the driver's cab at all times. This calibration must also be checked on site. Methods for calibration are given in the above references.

2. Spraying

The edge of the area to be sprayed is marked out with a line of string or wire pegged down at intervals not exceeding 15 m on straight lines or 7.5 m on curves.

Hand-spraying is permitted only in small areas that the distributor cannot reach or to make good defective areas, such as, those caused by a blocked nozzle.

Nozzles should be arranged to give a uniform spray and should be tested prior to spraying by discharging on to suitable material (such as, building paper , metal sheets, etc.) or into purpose made troughs. Testing should not take place on the road or directly onto the ground, and any bitumen spilt on the ground should be removed.

If, during spraying, a nozzle becomes blocked or develops a defect, the spraying should be immediately stopped. Any area incompletely sprayed should be made good with a hand- spray. The machine should be repaired before further spraying is carried out

At the points where spraying commences and stops, sheets of building paper or sheet metal at least 2 m wide should be spread across the full width to be sprayed to give a clean sharp edge, and provide a run- on and run-off, so that spraying at the required discharge rate is achieved throughout the length.

The metal sheets used for stopping and starting work should be cleaned after each run and the troughs used for testing should be cleaned at the end of each day's work.

During spraying, all kerbs, road furniture, culvert headwalls, and the like should be protected from bitumen spray, and any such feature which is accidentally marred by bitumen should be made good.

3. Tolerances

The rate of application of bituminous binder across the width of each spray run should not vary by more than ± 10 per cent from the rate ordered. The average application rate of binder for each single run of the spray truck should be at least equal to the rate ordered. Tray tests should be taken at least once a day during spraying operations to check calculations based on dipping of spray trucks.

4. Safety precautions

All necessary precautions should be taken to avoid fire. It should be ensured that operations in respect of bituminous construction work are not hazardous to the health and safety of the public or contractor's labour. In particular it should be ensured that:

(a) bitumen is heated only to the temperature required for the particular application;

(b) hot bitumen does not come in contact with water;

(c) excessive moisture is not present in the aggregate as it may lead to frothing . In case of frothing, addition of some hygroscopic material or anti-frothing agent may be required

(d) suitable protective clothing and gloves are supplied to , and used by , operators when handing tot bitumen;

(e) dust is reduced to a minimum;

(f) bitumen products and solvents are not spilt on to the ground nor into ditches nor into water courses;

(g) any bitumen products or solvents which are spilt are immediately removed along with any contaminated soil, etc. and disposed off in a place and manner such that environmental risks and hazards are negated;

(h) waste or over- heated bitumen or solvents are not disposed of by burning.

Because of the highly flammable nature of the solvent, great care is require when using rapid -curing cutback bitumen.

8.3.1. Prime coat (Clause 502 of Ministry's Specifications)

8.3.1.1. Weather and seasonal limitations: Bituminous primer should not be applied to a wet surface (except when emulsion is used as a primer, in which case the surface should be damp but not wet) or during a dust storm or when the weather is foggy, rainy, windy or when the temperature in the shade is less than 10°C.

8.3.1.2. Equipment : The primer distributor should be a self-propelled or towed bitumen pressure sprayer complying with the requirements given in para 6.3. Hand spraying of small areas, inaccessible to the distributor, may be allowed and power brooms and blowers may be supplemented by hand brooms.

8.3.1.3. Preparation of road surface: The surface to be primed is first prepared in accordance with para 8.2.4. The practice of producing a smooth finish on a graded granular base by wetting and heavy vibratory compaction, thereby drawing fines to the surface should not be permitted. The fines produce a weak surface layer and also inhibit the penetration of the primer. Immediately, prior to applying the primer, the surface should be carefully swept clean of dust and lose particles preferably using air compressor, care being taken not to disturb the interlocked aggregate. This is best achieved when the surface layer is slightly moist (lightly sprayed with water and the surface allowed to dry) and the surface should be kept moist until the prime is applied.

8.3.1.4. Application of bituminous primer: The viscosity and rate of application of the primer should be chosen so that the surface absorbs all it can, with a penetration of 5 mm to 10 mm, and only a thin film is left on the surface which dries quickly. Para 4.2.1.3. gives an idea the likely range for the rate of spray but the actual rate to be used must be determined by site trials. The bituminous primer should be sprayed uniformly in accordance with para 8.3.

The temperature of application must be high enough, and no higher, to permit the primer to be effectively sprayed through the jets of the spray bar and to cover the granular base surface uniformly in the desired quantity The binder temperature should be in accordance with the table 8.1.

Table 8.1. Binder Temperatures for Primers

Cutback Bitumens	Temperature Range
MC - 30	30°C - 55°C
MC - 70	50°C - 80°C
MC - 250	75°C - 100°C
Bitumen Emulsion	
SS - 1H, css - 1 OR css - 1H	20°C - 60°C

8.3.15. Curing of primer and opening to traffic : A primed surface is allowed to cure for at least 24 hours or such other period as is found to be necessary to allow all the volatiles to evaporate before any subsequent surface treatment or mix is laid. Any unabsorbed prime should first be blotted with an application of sand, using the minimum quantity possible A primed surface should not be opened to traffic other than that necessary to lay the next course.

There could arise a situation when a freshly laid and primed granular base in half width, awaiting bituminous base course, is to serve as diversion while the construction is in progress in the other half width of the road. In such a situation, a temporary wearing course of single coat surface dressing should be provided, in order to minimise damage to the primed surface.

8.3.1.6 Tack cot : Before laying a bituminous treatment or mix on a primed surface a tack coat should be applied in accordance with para 8.3.2.

8.3.2. Tack coat (Clause 503 of Ministry‘s Specifications)

8.3.2.1. Weather and seasonal limitations: Bituminous material should not be applied to a wet surface or during a dust storm or when the weather is foggy, rainy or when the temperature in the shade is less than 10°C. When emulsions are used a slightly damp surface is preferred.

8.3.2.2. Equipment : The tack coat distributor should be self - propelled or towed bitumen distributor complying with the requirements given in para 8.3. Hand spraying of small areas, inaccessible to the distributor, may be allowed and power brooms and blowers may be supplemented by hand brooms

8.3.2.3 Preparation of base: The surface on which the tack coat is to be applied should be cleaned of dust and any extraneous material before the application of the binder, by using a mechanical broom or any other approved equipment/method.

8.3.2.4. Application of binder: The binder is sprayed uniformly, in accordance with the requirements of para 8.2, at a rate within the range specified in Table 4.1, which is determined by trials on site. Work should be planned so that on more than the necessary tack coat for the day's operation is placed on the surface.

8.3.2.5. Curing of tack coat: The tack coat should be left to cure till all the volatiles have evaporated before any subsequent construction is started. The use of rapid setting cutbacks or emulsions for tack coat helps to keep the waiting time to the minimum. No plant or vehicles should be allowed on the tack coat other than those essential for the construction.

8.3.3. Bituminous penetration macadam (Clause 505 of Ministry's Specifications)

8.3.3.1. Weather and seasonal limitations: Bituminous material should not be applied to a wet surface (except when emulsion is used as a primer, in which case the surface should be damp but not wet) or during a dust storm or when the weather is foggy, rainy or when the temperature in the shade is less than 10°C.

8.3.3.2. Preparation of the bse : The base on which the Penetration macadam Course is to be laid should be laid should be prepared, shaped and conditioned to the specified lies, grades and sections to para 8.2.4. A prime coat wher needed, should be applied over the base in accordance with para 8.3.1. A tack coat as per para 8.3.2 should be applied.

8.3.3.3 Spreading and compacting coarse aggregates: The coarse aggregates in a dry and clean form are spread uniformly and evenly at the rate specified in Table 4.2 preferably with the help of a self- propelled or tipper tail mounted aggregate spreader capable of spreading aggregate uniformly at the specified rates over the required widths. The surface of the layer should be carefully checked with camber templates and all high and low spots remedied by removing or adding aggregates as may be required. If this adjustment is substantial the rate of spread should be adjusted accordingly. The spreading should be carried no further in advance of the rolling and penetrating operations than can be completed in that day's work. Segregated aggregates or aggregates mixed with eaeth or other foreian substances should be removed and replaced with graded aggregates.

8.3.3.4. Compaction: After the spreading of coarse aggregates, dry rolling is carried out with 8 to 10 tonne smooth -wheeled steel roller.

After initial rolling , the surface is checked with a crown template and 3 metre straight-edge. The surface should not vary more than 10 mm from the template or straight- edge. All surface irregularities exceeding the above limit should be corrected by removing or adding aggregates as required.

The rolling should be continued until the compacted coarse aggregate has a firm surface true to the cross-section shown on the plans and has a texture that will allow free and uniform penetration of the bitumen material.

8.3.3.5. Application of bituminous material : After the coarse aggregate has been rolled and checked, the bituminous binder is applied, at the specified rate. The spraying temperature of penetration grade bitumen should be 130°C+, the maximum the temperature being below that at which fogging occurs.

At the time of applying the binder, the aggregates should be surface dry for the full depth of the layer.

The volume of the applied bitumen is about one third the volume of the total voids in the compacted coarse aggregate. If it is found that insufficient bitumen is remaining at the top of the coarse aggregate mat to hold the keystone securely, consideration should be given to placing a bed of clean sand or quarry fines, not exceeding about 10 mm in thickness, on the prepared foundation before placing the coarse aggregate. During compaction the coarse aggregate will penetrate into this bottom layer. This operation will be assisted if the sand is slightly wetted, just sufficient for it to slurry up during the compaction process. These fines then effectively fill the voids at the base of the compacted coarse aggregate mat and prevent the applied bitumen from penetrating too far. When cutback is used, if flooding of the binder tends to occur it should be applied in two operations, half at a time.

8.3.3.6. Application of key aggregates: Immediately, after the first application of bitumen, the key aggregates in a clean and dry state, should be spread uniformly over the surface by means of an approved mechanical spreader or by approved manual methods at the rate specified in Table 4.2.

If necessary, the surface should be broomed and the quantity of key aggregate adjusted to ensure uniform application, with all the surface voids in the coarse aggregate being filled but without excess. The entire surface should then be rolled with 8 to 10 tone smooth steel wheel roller (alongwith a vibratory roller if available).

8.3.3.7. Surface finish : The surface finish of the completed construction should conform the requirements laid down in Chapter 10.

8.3.3.8. Surfacing : The penetration macadam should be provided with a surface (binder /wearing course) within one or two days. If there is to be any delay ,the course should be covered by a seal coat.

8.3.4. Built-up spray grout (Clause 506 of Ministry's Specifications)

8.3.4.1. Weather and seasonal limitations: Bituminous material should not be applied to a wet surface (except when emulsion is used as a primer, in which case the surface should be damp but not wet) or during a dust storm or when the weather is foggy, rainy or when the temperature in the shade is less than 10°C.

8.3.4.2 Preparation of base: of base: The base on which the built- up spray grout is to be laid 8.2.4 should be prepared, shaped and conditioned to the specified lines, grades and cross- sections in accordance with para A priming coat where needed should be applied in accordance with para 8.3.1 with suitable primer.

8.3.4.3. Tack coat: A tack coat over the base where needed should be applied in accordance with para 8.3.2.

8.3.4.4 . Spreading and rolling coarse aggregates for the first layer : Immediately, after the application of tack coat, the coarse aggregates in a dry and clean form should be spread uniformly and evenly, preferably by mechanical means, at the rate of 0.5 cum per 10 sqm area. The surface of the layer should be carefully checked with templates and all high and low spots remedied by removing or adding aggregates as may be required.

Immediately, after spreading of the aggregates, the entire surface should be rolled with 8 to 10 tonne smooth-wheeled roller. Rolling should commence at the edges and progress towards the centre except in super-elevated and uni-directional cambered portions where it should proceed form the lower edge to the higher edge. Each pass of the roller should uniformly overlap not less than one-third of the track made in the preceding pass.

After initial rolling, the surface should be checked transversely and longitudinally with templates and any irregularities corrected by loosening the surface, adding or removing necessary amounts of aggregate, followed by rolling .

Rolling should be stopped before voids in the aggregate layer which is closed to such an extent as to prevent free and uniform penetration of the binder

8.3.4.5. Application of binder-first spray: The binder should be heated to the temperature appropriate to the grade of bitumen approved by the Engineer and sprayed on top of the aggregate layer at the rate of 15 kg /10 sqm (measured in terms of residual bitumen content) in a uniform manner with the help of a mechanical sprayer capable of spraying bitumen uniformly at the specified rates and temperatures. The spraying temperature of penetration grade bitumen should be 130°C +, the maximum being that at which fogging occurs. Excessive deposits of binder caused by stopping or starting of the sprayers or through leakage or any other reason should be corrected promptly.

8.3.4.6. Spreading and rolling of coarse aggregates for the second layer: Immediately, after the first application of the binder, the second layer of coarse aggregates should be spread and rolled in accordance with para 8.3.4.4.

8.3.4.7. Application of binder-second spray: The second aggregate layer should then be give a binder spray at the rate of 15kg/10 sqm (measured in terms of residual bitumen content) in accordance with para 8.3.4.5.

8.3.4.8. Application of key aggregates : Immediately, after the second application of binder, key aggregates in a clean and dry state should be speed uniformly and evenly preferably, by mechanical means, at the rate of 0.13 cum/10 sqm so as to cover the surface completely. If necessary, the surface should be broomed to ensure uniform application of key aggregates. The entire surface should then be rolled with a 8 to 10 tonne smooth-wheeled roller in accordance with para 8.3.4.4. While rolling is in progress, additional key aggregates, where required, should be spread by hand. Rolling should be continued until the entire course is thoroughly compacted and the key aggregates are firmly in position.

8.3.4.9. Surface finish: The surface finish of construction should conform to the requirements laid down in Chapter 10.

8.3.4.10. Final surfacing : The built- up spray grout should be provided with final surfacing within one or two days. If there is to be any delay, the course should be covered by a seal coat.

8.3.5. Surface dressing (Clause 510 of Ministry's Specifications)

8.3.5.1. Weather and seasonal limitations: Bituminous material should not be applied to a wet surface (except when emulsion is used as a primer, in which case also, the surface could be only slightly damp but not wet) or during a dust storm or when the weather is foggy, rainy, windy or when the temperature in the shade is less than 10°C.

8.3.5.2. Preparation of base : The base on which the surface dressing is to be laid should be prepared, shaped and conditioned to the specified lines, grade and cross-section in accordance with para 8.2.4. Prime coat, where needed, should be provided as per para 8.3.1. Where the existing surface shows signs of fatting up, the excess bitumen should be removed by burning off or manually. The bituminous surface to be dressed should be thoroughly cleaned either by using a mechanical broom or any other approved equipment/method. Dust removed in the process should be blown off with the help of compressed air.

8.3.5.3. Application of binder: The equipment and general procedures should all be in accordance with para 8.3. The application temperature for the grade used should be as given in Table 8.2. The surface on which the binder is to be applied should be dry (in the case of emulsion binder the surface should be damp)

Table 8.2. Spraying Temperatures for Binder

Binder Grades	Whirling Spray Jets		Slot Jets	
	Min.°C	Max.°C	Min.°C	Max.°C
Binder Grades				
MC30	50	60	40	50
RC/MC 70	65	80	55	70
RC/MC 250	95	115	80	90
RC/MC 800	115	135	105	115
RC/MC 3000	135	150	120	130
Penetration Grades				
400/500	160	170	140	150
280/320	165	175	150	160
180/200	170	190	155	165
80/100	180	200	165	175

Notes: Because of the inflammable nature of the solvent used in RC- type cutbacks, application temperatures for RC grades should be restricted to the lower parts of the ranges given above.

Attention is also drawn to the need to extinguish flames and prohibit smoking when heating, pumping or spraying all cutbacks. Fire extinguishers should always be readily at hand.

8.3.5.4 Application of stone chipping : The equipment and general procedure should all be as described in Chapter 6. For relatively small areas of surface dressing careful application of chippings by hand may be acceptable. Immediately, after application of the binder, clean, dry chippings (in the case of emulsion binder the chippings may be damp) should be spread uniformly on the surface so as to cover the surface completely with a single layer of chippings. If necessary, the surface should be broomed to ensure uniform spread of chippings.

Where a significant loss of chippings during trafficking in wet weather is considered to be a risk, a suitable anti-stripping agent in the required amount may be added to the binder.

As an alternative to the use of anti-stripping agent, the chippings may be precoated before they are spread, except when the spread binder film is a bitumen emulsion. Precoating is likely to be particularly beneficial if the chippings are poorly shaped.

Precoating the chippigs may be done by one of the following two methods:

(a) Mixing them with 0.75 to 1.0 per cent of paving bitumen by weight of chippings in a suitable mixer, the chippings being heated to 160°C and the bitumen to its application temperature. The precoated chippings are allowed to cure for at least one week or until they become non-sticky and can be spread easily.

b) Spraying the chippings with a light application of creosote, diesel oil or kerosene at ambient temperature. This spraying can be done in a concrete mixer or on a belt conveying the chippings from stockpile to gritting lorries.

8.3.5.5. Synchronous spreading : A relatively recent technology of surface dressing aims at accurately coordinating with the operations of bitumen spraying and spreading of stone chippigs. With synchronous spreading, the inter-contact time between binder spraying and aggregate spreading is limited to one second. The spraying of bitumen automatically comes to a stop as soon as aggregate spreading ends, ie, there is never any excess of binder waiting for the aggregates to be spread. The new technology of synchronous spreading is specially beneficial when high viscosity binders are used and in areas with harsh climate and high evaporation.

8.3.5.5. Rolling: preferably, rolling of the chippings should be carried out by a pneumatic tyred roller. Traditional steel wheeled rollers tend to crush the aggregates and if their use cannot be avoided their weight should be limited to 8 tonne. Rolling should commence at the edges and progress towards the centre except in superelevated and uni- directional cambered portions where it should proceed from the lower edge to the higher edge, Each pass of the roller should uniformly overlap not less than one-third of the track made in the preceding pass. While rolling is in progress additional chippings should be spread by hand in necessary quantities required to make up irregularities. Rolling should be continued until all aggregates particles are firmly embedded in the binder and present a uniform closed surface.

8.3.5.6. Application of second coat of surface dressing: Where surface dressing in two coats is specified, the second coat should not be applied until the first coat has been trafficked for 2 or 3 weeks. The surface on which the second coat is laid must be clean and free of dust. The construction operations for the second coat is laid must be clean and free of dust. The construction ooperations for the second coat should be the same as described in paras 8.3.5.3. to 8.3.5.6.

8.3.5.7. Opening to traffic: Traffic should not be permitted to run on any newly surface dressed area until the following day. In special circumstances, however, the roads may be opened to traffic immediately after rolling, but in such cases traffic speed should be limited to 16 km/hr until the following day.

8.3.5.8. Surface finish: The surface finish of construction should conform to the requirements laid down in Chapter 10.

8.3.6. Liquid seal coat (Clause 513 of Ministry's Specifications)

8.3.6.1. Weather and seasonal limitations: Bituminous material should not be applied to a wet surface (except when emulsion is used as a primer, in which case the surface should be damp but not wet) or during a dust storm or when the weather is foggy, rainy, windy or when the temperature in the shade is less than 10°C.

8.3.6.2 Application of binder : Straight-run bitumen should be heated to 150°C - 163°C depending on the grade (the maximum temperature being below that at which fogging occurs), and sprayed at the specified rate on the dry surface free of any dust or lose material, in a uniform manner with help of self-propelled mechanical sprayers as described in Chapter 6 and para 8.3. If a cutback or emulsion is used the same may be sprayed at the rate specified following the spraying procedure as given in paras 8.3.1 and 8.3.2.

8.3.6.4. Application of stone chippings: Immediately after the application of binder, stone chippings should be spread uniformly at the rate specified on the surface by means of a self- propelled or towed mechanical grit spreader so as to cover the surface completely. If necessary, the surface should be broomed to ensure uniform spread of chippings.

8.3.6.4. Rolling : Immediately, after the application of the cover material, the entire surface should be rolled with a 8 to 10 tonne smooth - wheeled steel roller, 80 to 10 tonnes static weight vibrating roller, or other approved equipment. Rolling should commence at the edges and progress towards centre except in superelavated and uni-directional cambered portions where it should proceed from the lower edge to the higher edge. Each pass of the roller should uniformly overlap not less than one-third of the track made in the preceding pass. While rolling is in progress, additional chippings should be spread by hand in necessary quantities required to make up irregularities. Rolling should continue until all aggregate particles are firmly embedded in the binder and present a uniform closed surface.

8.3.6.5 Opening to traffic: traffic should not be permitted to run on any newly surface dressed area until the following day. In special circumstances, the road may be opened to traffic immediately after rolling, but in such cases traffic speed should be limited to 16 km/hr until the following day

8.3.7. Fog spray (Clause 518 of Ministry's Specifications)

8.3.7.1. Weather and seasonal limitations: Spraying should not take place when it is raining or the surface to be sprayed is wet or when the temperature is less than 10°C, or in windy or dusty conditions.

8.3.7.2. Equipment: The fog spray should be applied by means of a self-propelled or towed bitumen pressure sprayer complying with the requirements of section 8.3. The spray bar should be protected from gusts of wind by means of a hood.

8.3.7.3. Preparation of base : The surface on which the fog spray is to be applied should be thoroughly cleaned of all dust, dirt and loose material. Unless low bitumen content emulsion (45 per cent) is being used the surface should be lightly dampened .

8.3.7.4. Application: The rate of application of the emulsion should be determined by trials on site using the following ranges as guides:

a) Either 0.45 to 0.9 litres/m2 for the grades mentioned in para 4.2.7.3 (after dilution with water); or

b) 0.45 litres/m2 for the BS grades (without dilution)

If blinding is applied, see also para 8.3.7.5.

8.3.7.5. Blinding : The fog spray should be blinded as follows:

After the emulsion has started to break, a light coating of bitumen coated grit should be applied to the sprayed surface. The grit should consist of fine material, graded from 3 mm to dust with not more than 10 per cent passing 0.075 mm sieve, coated with not more than 3.5 per cent by weight of bitumen. The rate of application should be between 2.5 kg/m^2 to 5 kg/m^2 according to the texture off the surface. When the required rate is at the high end, the rate of application of the fog spray should be increased by approximately 50 per cent. Richly coated grit should be avoided because it cannot be spread uniformly by mechanical gritters and may not work into the carpet satisfactorily.

8.3.7.6. Quality control of work : For control of The quality of materials supplied and the works carried out, the relevant provisions of Chapter 10 apply.

8.3.7.7. Arrangements for traffic: During the spraying operations, arrangements for traffic should be made in accordance with para 8.2.3. The surface should not be opened to traffic for 24 hours after spraying. If pick- up does occur, a light blinding of crusher dust or sand should be applied.

8.4. Pre-mix Methods of Construction

In this type of construction, the aggregates and bituminous binder are mixed beforehand in a suitable plant, before laying and compaction. Most of the high quality bituminous surfacing for pavements subjected to high speed traffic and high load intensity traffic (where high structural strength and high level riding quality requirements are to be satisfied) are constructed by premix methods using plant mixes. Basically there are two broad types of plants, viz., Batch plant and Drum Mix plant(Figs 8.14 and 8.15)used for the mixing of aggregates and bituminous binder (See para). 6.5. The various requirements for mixing plants, salient aspects of hot-mix operation, safety measures, transportation of materials, paving operations and rolling operations followed by salient construction aspects of different types of bituminous base, binder and wearing courses are given in the following paragraphs.

8.14. A Typical Batch Type of Hot-Mix Plant

8.4.1. General requirements for hot mix plants

a) The capacity of a hot mix plant should be denoted by the output rating of the hot mixed material (in tonne Per hour) at 5 per cent and 2 per cent moisture content in aggregates and aggregate output temperature of 170°C.

b) The materials used in the manufacture of various components, in ancillary equipment and in power units should be in conformity with the relevant Indian Standards or International Standards, if manufactured abroad.

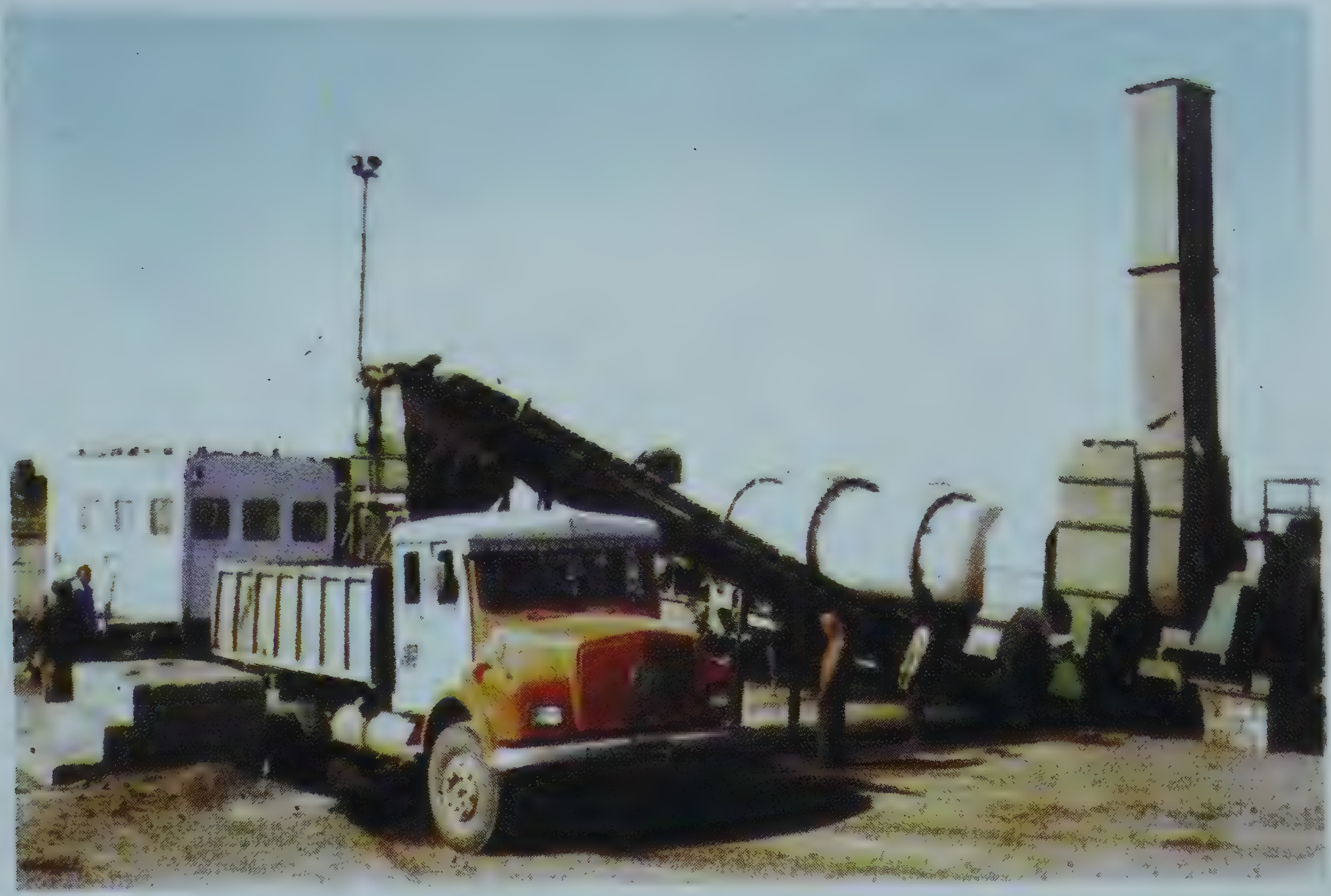


Fig. 8.15. A Typical Drum-Mix Plant

(c) The plant should be classified as (i) Static, when designed to be erected on a permanent site with no special arrangements to facilitate its removal, (ii) Portable, when so designed that it may be easily disassembled into sections which may be transported by road or rail, (iii) mobile, when so designed that it may be readily separated into sections (dimensions not exceeding 10 m x 3 m x 4.5 m), equipped with pneumatic tyres of adequate size and overrun and parking break.

(d) The plant should be able to function in a wide range of temperatures (preferably 20°C to +55°C) and relative humidity. Also, it should be suitable for operation at high attitudes and in high wind velocity (preferably upto 120 km /hr).

(e) The various power units should be capable of being driven, either individually or in combination, by electric motors, as may be specified.

(f) The design of the plant should provide convenient accessibility to all components, sub-assemblies and parts for cleaning, maintenance and repairs.

(g) Adequate unobstructed space should be provided on the mixing platform with easy and safe access to a location above the mixer to obtain samples of aggregates in the bins and also in and around the truck loading space with a ladder of platform to permit easy and safe inspection of the mixture being delivered into trucks.

h) The various components should be so designed that overloading of any part as a result of jamming is immediately relieved by breaker bolts or shear pins or similar devices.

i) Gearing should be so designed as to have ample strength and to adequately withstand wear and temperature rise.

j) Lubrication means should be provided for all bearings and all other moving parts requiring lubrication.

8.4.2. Hot mix plant operation

8.4.2.1. Principles of good operation: the following principles govern the operation of a modern hot-mix plant:

1. The operations should be carefully planned, so that the final product is of a high quality.
2. The operation should be run by a competent manager, who, with his supporting staff, are fully conversant with the plant, its operation and maintenance.

3. The basic aim should be to achieve a smooth continuity of operations, devoid of breakdowns and intermittent working. This will ensure uniformity of the final product.
4. The output of the plant depends on the well co-ordinated supply of all necessary ingredients. Thus adequate stock of these must be ensured, at all times.

8.4.2.2. Batch type plant operation

(a) **Cold-feed Supply :** The quantities of aggregates of each size needed for the required production should be carefully calculated. The cold aggregate feeder gates should be calibrated based on the proportion of aggregates of each size needed for each mixture. It is advisable to have a vibratory arrangement fitted to the fine aggregate bins to ensure good flow of aggregates. The belt conveyors for each bin have variable speed drive motors. These enable the rate of cold feed to be accurately controlled. Electronic sensors on the conveyor measure the flow of aggregate in modern plants. The cold feed bins should have screen of square mesh grizzly of size 20 mm higher than maximum particle size being used in the mix design to prevent entry of oversize material. Opening of the bins should be large enough to facilitate filling of bins directly by dumpers, wheel loaders. Bins should have partitions to prevent intermixing. Side wall slope of 67° will help to eliminate bridging. The feeder bins should be made out of such steel that there is no distortion when fully loaded and should be painted with anti-rusting compound.

(b) **Dryer Operation:** The dryer is the basic part of any mixing plant, its function being to remove the moisture in the aggregates and to heat them to the required temperature. The drying unit is very fuel intensive, and hence affects very significantly the cost of the final product. About 10 litres of fuel per tonne of aggregates are required to remove 5 per cent of moisture and increase the temperature to 160°C. For hot bituminous mixes, the specifications require that the temperature of hot aggregates should be in the ranges of 140 - 165°C; 150 -170°C and 160 - 175°C for mixing with bitumen penetration grades of 90, 65 and 35 respectively and that the temperature of hot aggregate should not be more than 14°C higher than that of bitumen. Correspondingly, the temperature of the binder at the time of mixing with aggregate should be in the range of 140-160°C, 150-165°C and 160-170°C for bitumen penetration grades of 90, 65 and 35 respectively. For modified binders, as per IRC:SP:53, the temperature of binder at the time of mixing should be in the range of 145 -165°C. A typical dryer and built-in dust control system are shown in Figs 8.16 and 8.17 respectively. The dryer drum should be made of high strength alloy steel and have insulation of ceramic wool or any other suitable material of suitable thickness covered with aluminium sheet to prevent wastage of heat. Inside the dryer, a series of lifters/flights should be bolted/welded, designed to cascade material across the diameter of the drum, as per design. A variable flame length burner suitable to use LDO/K Oil/ Diesel fuel should be fitted at the discharge end. The burner should have automatic thermostatic control to regulate the flame. At the discharge end, suitable means (eg., sensor of pyrometer type) should be should be provided for ascertaining the temperature of heated aggregate. Burner control should have provision of setting alarm temperature at which flame will be cut-off, automatically.

(c) **Dust Collector and Pollution Control:** The hot gases coming out of the dryer drum are loaded with fine particles and should not be released into the atmosphere. For the protection of the environment, the plant should be equipped with baghouse filter (details in para 6.5.8, Chapter 6). A Suitable sized hopper with screw conveyor is provided for collecting the reclaimed fines and feeding to the mixer in the required quantity. When recovered fines are not to be used as filler, they are to be separated from the air stream by water in a scrubber. The plant should conform to emission standards for hot mix plants prevailing in the State/Central Pollution Control Board.

(d) **Vibratory Screens :** The heated aggregtes should be separated into various sizes by the hot screens, and stored in separate hot bins. The vibratory screens are arranged in a deck with the smallest particle size falling into the first bin. In rotary screens, the production gets reduced; therefore, these may be used only where lesser output is acceptable. The screens should be periodically inspected, and plugged openings should be cleaned. When screens get worn, they should be replaced. Daily inspection before the start of the operations is essential.

(e) **Batching :** The hot bins receive the screened material of various sizes. The capacity of the hot bins should be sufficient to prevent depletion of the material when the mixer is in operation at full capacity. An analysis of the representative samples from the hot bins facilitates the determination of the proportion of each material to be discharged into the mixer. The final proportions should be such that the combined gradation is nearly equal to the one determined in the job-mix formula.

The weighing system must be regularly checked and any defects detected must be rectified immediately. The bitumen weighing scales must also be regularly checked for accuracy.

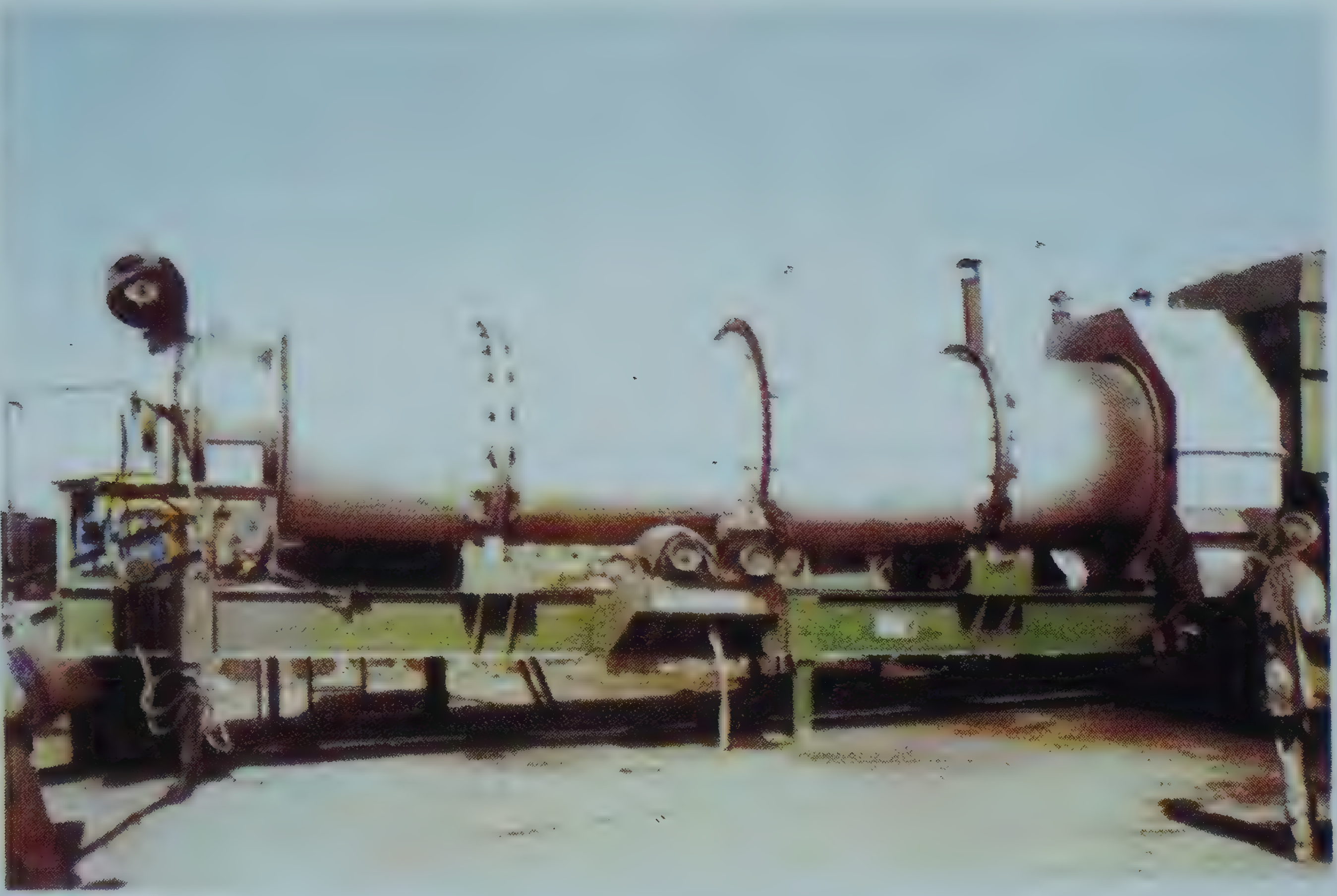


Fig. 8.16. A Typical Dryer

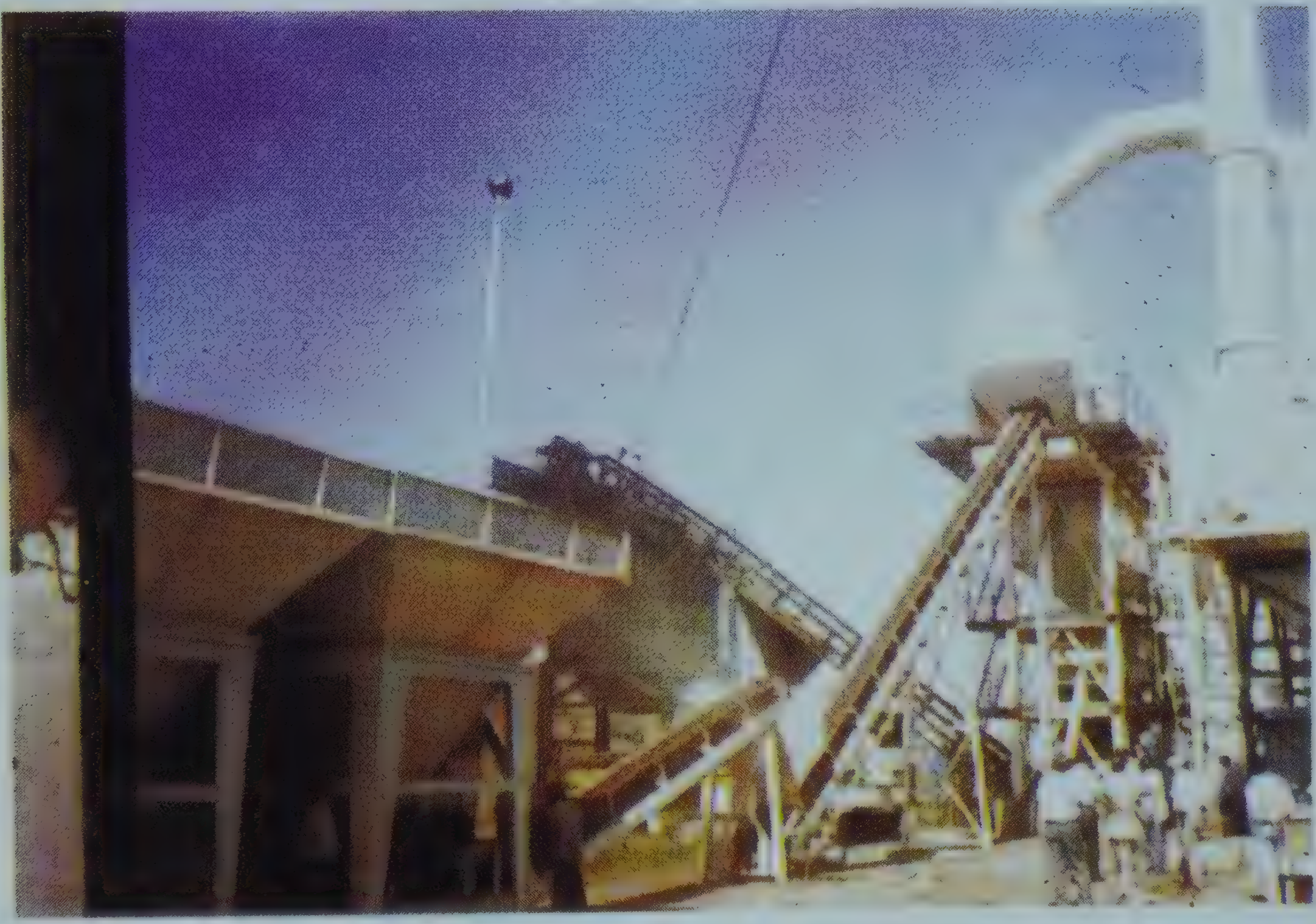


Fig. 8.17. A Built-in Dust Control System

The conventional method of discharging materials into the mixer begins with the largest size aggregates and proceding progressively down to the smallest size, the filler, finally followed by the bitumen. The weight of each ingredient is recorded. A set of load cells should be fitted for accurate weighing of each size of hot aggregates with continuous display of weight in control panel.

(f) **Mixing :** The pug-mill should be periodically inspected to ensure proper functioning and correct adjustment. The paddle faces must be set at the correct angle as recommended by the manufacturers. The mixer must always be filled to its optimum level, as overfilling and under-filling are detrimental to production of a constant mixture. The mixing time starts at the opening of the weigh box hopper gate and is completed with the discharge of the mixture into the receiver trucks. Mixing time can be determined by following a simple test procedure laid down in AASHTO T195 (ASTM D2489). After separating coarse aggregate particles from the mix on a selected sieve size, about 200 to 300 particles should be examined under a strong light. Any speck of uncoated aggregate particle visible to the naked eye classifies that particle as "uncoated". For use in base and surface courses, 90 and 95 per cent "coated" particles respectively are considered absolute minimum values. The least time needed for achieving these minimum standards is the mos desirable mixing time. A pneumatically operated gate should be provided for quick discharge of the mix and movemen of hot mix upto the tipper should be in a covered path.

8.4.2.3. Drum mix plant operation

(a) **Aggregate Control :** The cold aggregate feeder should have four bins (not less than three, in any case), each bin provided with adjustable gates to regulate the flow of aggregates at a uniform and predetermined rate to the dryer. Thy capacity of the feeder with gates half closed should not be less than the capacity of the dryer. Unlike, a batch type plant, the drum mix plant does not have a gradation screening unit and it is, therefore, absolutely, necessary that the aggregate must be correctly proportioned before its entry into the mixing drum. For this purpose, a cold feed system equipped with precision belt feeders should be provided for the control of each aggregate; under each bin, there should be a belt feeder onto which the aggregate is proportioned.

A single deck vibratory screen should be provided at the discharge end of the conveyor in order to reject any oversiz material above the permissible limits.

A slinger conveyor should be provided for transferring the aggregate received from the vibratory screen into the dryer under combustion zone. It consists of head, tail pulleys, carrying idlers, return roller and tensioning device. Before the aggregate is fed into the drum mixer, its weight is sensed and transmitted on a display panel. The speed of the conveyor belt is also considered, whereby, the display panel gives the rate of flow of aggregate in terms of tonnes/hours. As the weight of aggregate includes the weight of moisture contained in the aggregate, the weight of moisture (based on actual moisture content determination) should be subtracted to get the feed rate of dry aggregate required for the needed mix formulation.

(b) **Bitumen Metering :** The weight of aggregate entering the dryer-cum-mixer drum per unit time (tonnes per hour) is the basis for the determination of the quantity of bitumen (in litres per minute) to be added inside the drum. The bitumen metering and supply is a continuous mechanical proportioning system interlocked with the aggregate weigh system to attain the exact bitumen content (per cent by weight of dry aggregate) in the mix design. The bitumen content is, thus adjusted according to the corrected dry weight measurement of aggregate passing over the belt scale. The rate of supply of bitumen, in litres per minute is indicated on the display panel. Continuous graphs of the rates of aggregate and bitumen are obtained, located in the control van.

(c) **Mixing :** The process of drying and blending of the aggregate and mixing of bitumen and aggregate all take place in the drum. Typically, there are two zones inside the mixer (i) primary or radiation zone and (ii) secondary or convection/ coating zone. The aggregates enter the drum at the burner end in the primary or radiation zone (where the heat emanating from the burner dries as well as heats the aggregate) and then travels to the secondary or convection/ coating zone where bitumen is added to the heated aggregate and both are thoroughly mixed with each other. Certain amount of drying of aggregate also takes place in the secondary zone. As a result of heating, the moisture removed from the aggregate and bitumen yield a foaming mass which absorbs the fine dust and helps in coating of coarse aggregates.

(d) **Dust Collection System :** The dryer-cum-mixer drum should be provided with a dust collector (see also Chapter 6) so designed that a proper balance should be achieved between air flow necessary for optimum drying performance and that which will permit proper dust control. The exhaust fan should be provided with chimney and with a damper. The exhaust capacity of fan should be sufficient to extract hot gases and capable of providing an even flow of adequate air volume and collecting and returning a portion of fine dust to the mix. The whole air pollution control system should have 95% efficiency of the cyclone dust collector in removing particulate matter above 15 micron size while the Wet Scrubber should have 98.5 per cent efficiency to take care of particulate matter below 15 micron size.

(e) **Hot Mix Storage :** A drum-mix plant produces a continuous flow of fresh bituminous mix and it is necessary to have a surge silo for temporary storage. The hot mix storage silo, insulated with thermo/ceramic wool or through hot oil circulation system, equipped with elevator should be provided for storage of the hot mix for a duration of upto 3 hours atleast.

8.4.2.4. Safety aspects

1. No open fires should be allowed around bitumen or fuel soil storage tanks
2. Control valves, which can be operated from a safe distance, should be installed.
3. All gears, pulleys, chains, belt sprockets, couplings, dangerous moving parts and parts which are subjected to high operating temperatures or are energised electrically should be insulated, well-guirded and protected.
4. Covered stairs and platform ladders should be provided to all parts of the operating plant.
5. All stairs and platforms should have handrails.
6. There should be no leaks in steam lines or jacketing on bitumen distribution lines.
7. Safety valves should be installed in all steam lines.
8. There should be no leakage in hot oil heating lines.
9. The bitumen level should never be allowed to go so low as to suck air or cause a dry mixture.
10. There should be a platform near the truck loading area from which the mix may be observed and from which temperature of the mix in the truck may be taken.
11. There should be an emergency switch located at a short distance from the plant, which will stop all plant operations in the event of an emergency.
12. Installation of combustion devices, boilers and fuel tanks should conform to safety regulations.
13. Lubrication means should be provided for all bearings and all other moving parts requiring lubrication.
14. Fire extinguishers should be installed at all strategic points.
15. A First Aid Box should always be available, in the control room.

It is desirable, if not necessary, that all workers engaged in the operation of bituminous plant and machinery should be adequately covered by risk insurance.

8.4.3. Transportation of materials

8.4.3.1. Number of vehicles : Careful planning is required to ensure that an adequate number of sport transport vehicles are allocated to any bituminous construction task.

Factors to be taken into account are:

- the steady average speed of the vehicles;
- the capacity of the trucks;
- the plant production capacity;
- the distance of the paving site from the plant;
- the condition of the haul road, the intensity of traffic and congestion;
- the number of pavers to be fed; and
- the maximum capacity of the pavers.

Since it is extremely important to maintain a regular uninterrupted flow of supply, provision for stand-vehicles must also be made, to ensure adequate numbers of operational transport vehicles at all times.

8.4.3.2. Truck operation : Mixed bituminous material loaded into trucks must be spread in the truck box evenly and not in heaps, which encourage segregation.

Vehicles should, insofar as is practicable, move smoothly at a steady speed, without unnecessary jerks and sudden braking which may cause segregation in the mix.

While backing towards the paver for discharge the truck must proceed with care, with a slight but steady application of brakes so that it makes gentle contact with the paver. Even a mild jolt may tilt the orientation of the paver hopper with respect to the alignment of the spread line and may also create a transverse ripple across the layer.

Contact between the transportation trucks and the paver must only be through the wheels of the truck with the rollers of the paver which are specifically meant for this purpose (Fig. 8.18). No .other part of the truck frame should be in contact with any part of the paver, nor should it bear any part of its weight on the hopper which may adversely affect the paving operation.

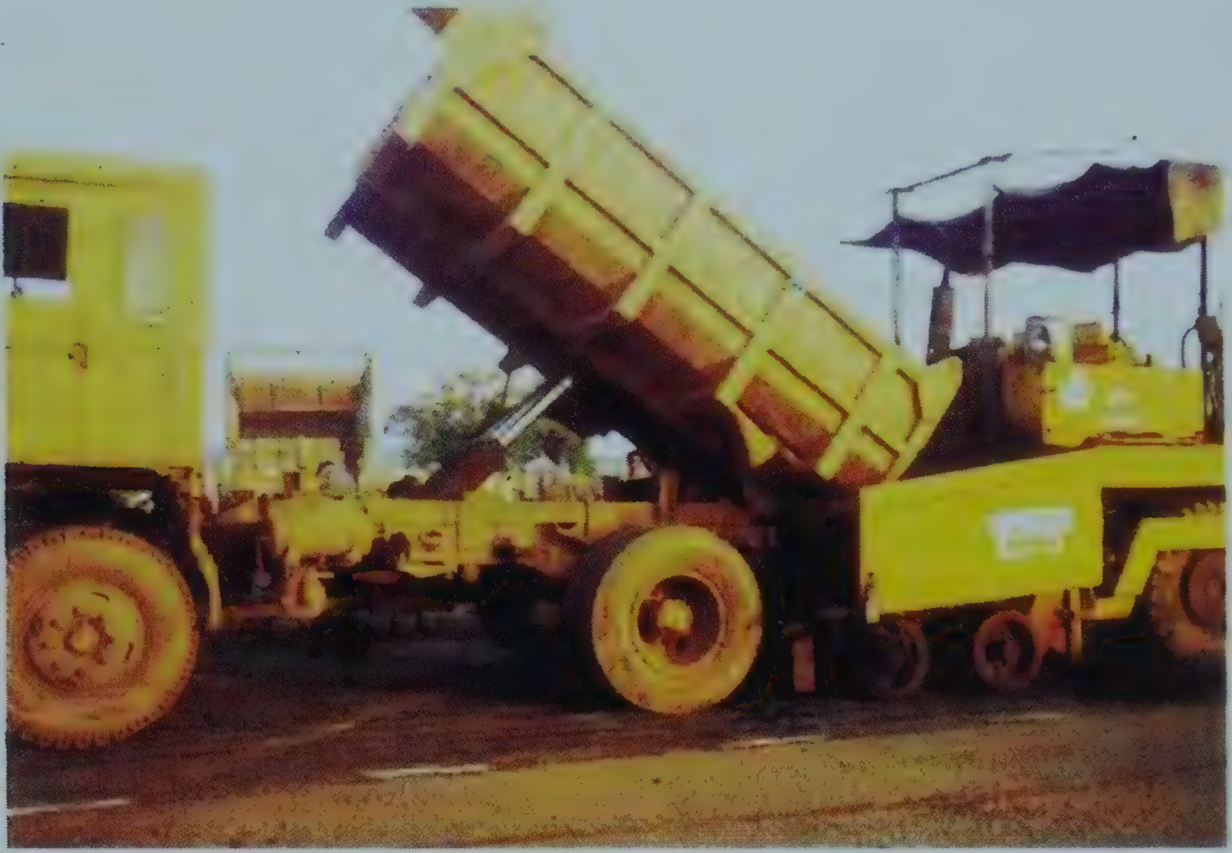


Fig. 8.18. A view of Truck Unloading Bituminous Mix in the Hopper of Paver

When the truck is unloading its charge in the hopper, both sets of its rear wheels must be in contact with the rollers of the paver. Absence of equal contact may skew the hopper and the whole spreading may require subsequent correction or replacement of the bituminous mixture.

While loading into the hopper the truck should be operated with a very slight application of the brakes so that its wheels are always in contact with the hopper rollers. The process of delivery of the material from the truck to the hopper must necessarily be slow and should be completed over a distance. If the driver attempts to discharge the load too quickly the hopper will be over-filled and bituminous mixture may spill on the side of the truck creating a layer of non-uniform material deposit.

The end gate of the truck must be opened fully while discharging into the hopper. Partial opening or a material blockage may lead to segregation.

8.4.4. Paving operations

8.4.4.1. Care in paving operations : There are a large number of points requiring careful attention to produce quality paving work, for which some of the more important ones are described below:

1. A fully detailed work plan for coordination of production of bituminous mixture and its laying and compaction must: be established before work commences, and all necessary equipment, materials and labour must be in place prior to the commencement of work.

2. The bottom of the screed plate must be inspected and seen to be clean.

   Similarly, the hopper sides, screws and conveyors should be clean and without any old mix material sticking to them. The two small blades on the screed shafts, which feed mix inwards, into the gap created by the central bearing housing, must not be worn or broken.
3. Prior to commencement of paving operation, the screed and tampers should be heated to the required temperature.

   All other metallic tools and implements, shovels, boards, etc. should be heated separately on a pan.
4. The screed (and tampers) should be heated after being placed on blocks equal in thickness to the level of the loose material to be laid and not while in contact with the existing pavement.
5. Work may only commence after confirming the availability of a continuous supply of material, ensuring that all component parts of the paver machine are functioning properly and the fuel tanks are full for continuous work and establishing that there is no break or uncertainty in the entire flow chain of production, transportation and laying.

The above steps are essential because any stoppage of paving in mid-course is likely to have expensive and time-consuming consequences.

When work is stopped, the stationary screed tends to sink into the bituminous material. The material covered by the screed retains its temperature but the material deposited in a heap in the hopper tends to form lumps. The material already laid out but which cannot be compacted by rollers (which cannot approach too close to the paver) cools. When the paver is activated again, the screed,. on being forced to move from a hotter to a cooler material, its level moves up and forms a ridge. The difficulty of proper compaction of the cooled material is an added burden. These difficulties are likely to lead to a defect in the surface finish and possibly to rejection, resurfacing, wastage of costly material and provision of a forced transverse joint at the location. Segregation and other blemishes in the uncompacted surface can usually be overcome by the "rake man", and the crew who work behind the machine. This is very skilled work, which must be carried out before the first rolling.

A view of the bituminous mix being spread by the paver is shown in Fig 8.19.

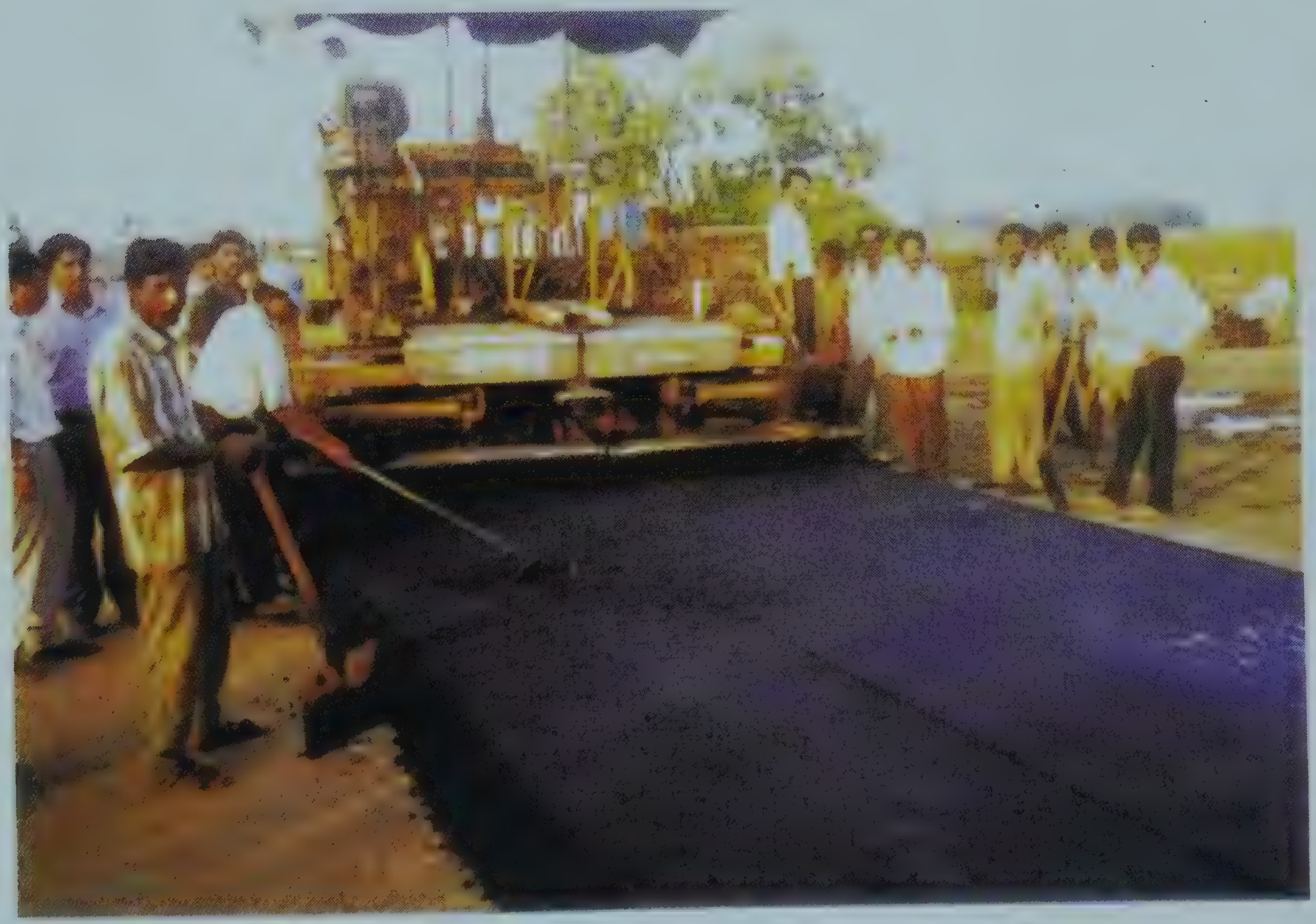


Fig. 8.19. Bituminous Mix being Spread by the Paver

With particular reference to the setting of the screed, and the selection of the speed of the paver first spread obtained should be critically examined both before and after rolling.

The spread surface should be checked with a straight edge and the uncompacted mat inspected for proper grade and line. If required, necessary adjustments of the hopper feed, spreading screws, tampers/vibrators and the screed inclination should be made in the light of the surface obtained.

8.4.4.2. Segregation

(a) By far the most common problem in construction with bituminous mixtures is segregation. If segregation of the material is observed, spreading operations should be immediately suspended, and the cause of the segregation identified remedied before resumption of work.

Segregation may occur

- in the mixing plant,
- during transportation of the mixture, or
- as a result of deficiencies in paving operations.

The common factor in segregation is the separation or partial separation of coarser material in a mix from the finer material by the action of gravity. After laying, areas of mix with excess of coarse material attract attention because they detract from the smoothness of the finished surface. However, the major problem is mainly with the remaining which is deficient in coarser sizes: it contains a disproportionate percentage of bitumen and is prone to bleeding and all the other problems associated with low air voids.

(b) **Segregation at the Plant:** In a hot mix plant, segregation may be due to the following:

1. Arching or hang-up of feeds may occur in the bins (specially because of moisture in fine aggregates) leading to its subsequent collapse suddenly releasing an excess of fines into the mix.
2. Provision of inadequate mixing time in the pug mill and release of material before uniform mixing is achieved.
3. Lack of timely replacement of broken, twisted or otherwise ineffective paddles in the pug mill.
4. The level of material in the pug mill being too high or too low.
5. Pugmill gate not opening quickly and smoothly for discharge. As a result the discharge comes out in lumps not in a smooth flow.
6. When the mix is in motion, either in free fall or sliding down a steep chute into a hopper or truck body.

Common reasons for segregation in drum mix plants are:

1. Overloading of drums causing flights to miss some aggregates,
2. Damaged or ineffective flights,
3. Insufficient mixing time.

In a hot mix plant, segregation is more likely to occur in the contents of the hot bins than in those of the cold feed bins.

In mixes where segregation is a persistent problem, a slight decrease in the minus 75 micron fraction (to decrease percentage of surface to be coated) may be resorted to, provided that the design can range accommodate a small change.

Mixing at too low a temperature, resulting in insufficient coating of material may also lead to segregation. Temperature correction is the appropriate remedial measure in such situations. However, in many drum mix plants when sometimes low temperature occurs due to higher percentage of retained moisture in the aggregates, the defect may not manifest in the form of segregation because of the presence of moisture.

(c) **Segregation in Transport :** During transportation, segregation may result due to the following:

1. Especially for coarse-grained mixes, if the material deposited is not uniformly spread out in the truck bed but is deposited in heaps of conical formation. During movement the coarse aggregates roll down the slope of the cone and collect at the outer edges of the cone.

   One way to avoid this is to move the truck during batch loading, so as to ensure a more even distribution of the bituminous mixture
2. If a small batch charge is deposited in a large truck body where it will be in a heap with unsupported sides for the coarse aggregate tend to roll down and collect at the bottom of the pile, as in 1, above.
3. If, when discharging into the paver hopper the rear gate of the truck does not open fully, the partial openings will prevent smooth flow and cause hang-up, resulting in segregation during fall.
4. Formation of segregated bands at the edges of the lane may be due to segregation on both sides of the delivery truck during its journey and the material being dropped in the paver hopper in this condition.
5. Likewise, segregation of material at the front and back of the truck bed may give rise to the occurrence of transverse segregated zones along the lanes.

(d) **Segregation in a Paver Finisher :** Segregation may occur during paver laying due to the following reasons:

1. If the spreading screws are working with insufficient material, the screw movement may throw larger particles towards the edges, causing segregation.
2. Conversely, if there is too much material with a large quantity above the level of the auger, the top material above the live zone will not be moved by the screw and will simply slide to the edges resulting in segregation. The golden rule is to keep the spreading screws submerged in material about two-third of their height to get the best result.
3. If the level of the auger is fixed too low, it may result in a rough open-textured surface.
4. It is .believed that the central drive system for two piece augurs (with gears and bearings in the middle) is also, to an extent, responsible for segregation and formation of a segregated stretch in the middle of the lane.

   In some makes provision of paddles on the auger shafts, adjacent to the central housing, has been made to avoid the problem. However, worn or broken paddles often occur and cancel this benefit.
5. Coarser, leaner mixes are more prone to segregation. Even more care and attention is, therefore, required against the formation of segregated zones in road base courses (rather than in wearing courses) and in surfacing with harsh mixes.

8.4.4.3. Construction of paving joints

(a) Transverse Joint (Day Joint)

1. The construction of transverse joints, (joints perpendicular to the normal direction of traffic flow) requires thorough care, as even a minor deficiency in its compaction, level or smoothness will be immediately reflected in the riding quality of the surface. The construction of transverse joints, therefore, requires very thorough compaction and smooth merging with the surrounding surface.
2. For a hot mix bituminous rolling job, the day's work starts with one transverse joint (where the previous day's work was left) and, in the absence of forced interruptions, ends on another one at the end of the day's operations.

   When the last charge of the day is being spread and the paver is to stop soon, with material falling below the two-third level of the auger, arrangements are made to leave a transverse joint in the surface.
3. Stoppage or interruption in paving work for any reason (such as, in the event of mechanical failure, etc.) will also need provision of a transverse joint at the location where work was stopped.

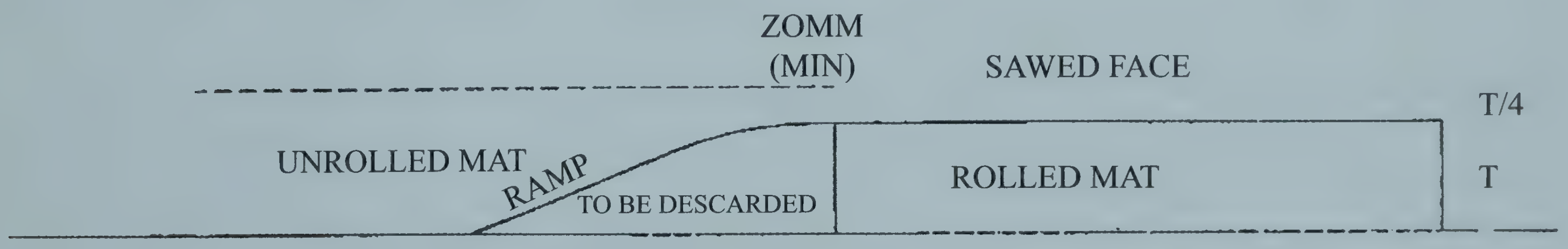
4. A transverse joint can be formed with a vertical face or with a sloping face.

5. A vertical face can be obtained with the help of a heavy wooden support beam with vertical sides and straight edges and of the same thickness as the layer. The wooden beam is placed in front of the paving operation (Fig. 8.20 a) at a point where paving is to be halted. The wooden beam can be additionally supported by an amount of mix material on the side furthest from the approaching construction, forming a short ramp. As soon as the paver screed passes over the beam, paving work is stopped for the day, the paver is shifted and the mat upto the beam compacted.

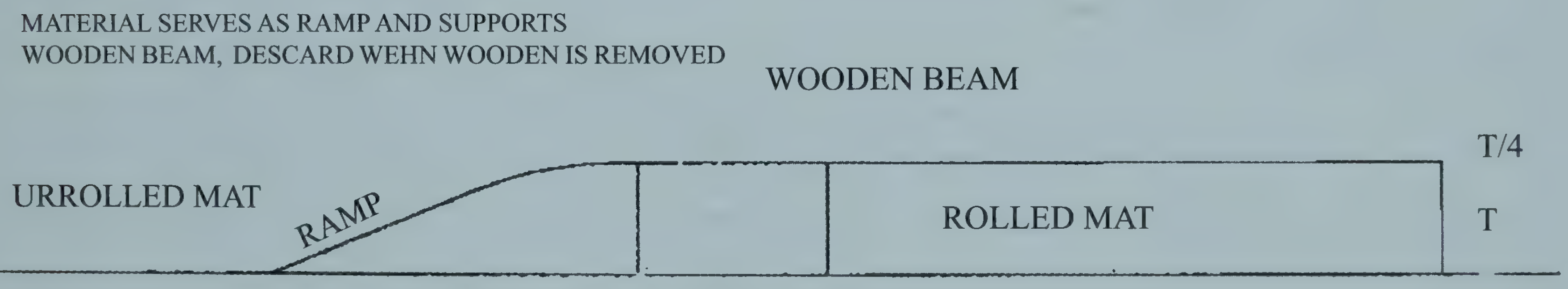
   The beam and the supporting ramp, if any, are removed on commencement of work on the subsequent day before the paver is in place to resume construction.

6. An alternative method for achieving a vertical transverse joint is for the paver to lay material at the design level upto the location of the joint and then form a short smooth ramp. All the placed material, including the ramp, must be compacted.

   On re-commencement of the work the ramp must be removed and a vertical face created by sawing through the mat Fig. 8.20 (b), the point of sectioning being at least 25 mm back from the end of the full thickness mat where compaction is assured.



(a) Constructing Transverse Joint having a Sawed Vertical Fac


MATERIAL SERVES AS RAMP AND SUPPORTS
WOODEN BEAM, DESCARD WEHN WOODEN IS REMOVED
WOODEN BEAM
T/4
URROLLED MAT
RAMP
ROLLED MAT
T

(b) Constructing Transverse Joint using Wooden Beam

Fig. 8.20. Construction of Transverse Joint

7. If a sloping joint is to be constructed, the material must be carefully formed and shaped into the slope with the help of a wooden straight edge and then adequately compacted along the slope before leaving work for the day.

   The next day the screed will start working from the point where the level starts tapering, the new material thickness on the sloping portion being carefully arranged by straight edge to loose thickness which is expected to give the correct level after compaction.

   When the final surface is not of the correct level, because of differential thickness of compaction along the slope, the material, while still hot, should be loosened, additional material placed or excess material removed and the mat on the slope again compacted to correct thickness.

8. When executed with care, both types of joint function well. A vertical face is easier to construct but involves some waste of material. A sloping joint requires additional care during construction but does not lead to any loss of material and according to some, provides a better seal as, with time, it is progressively compacted by traffic. The longer length and larger surface of contact between the new and the old material discourages ingress of moisture.

However, this method involves raking out a possibly 15 mm max size to zero, and possibly crushing of some stone in the second layer aggregate. With a tapering section the additional thickness to be laid taking into account compaction, varies along the ramp, and a satisfactory longitudinal profile difficult to achieve. A vertical joint cut with a saw or jackhammer and painted with bitumen is often preferred.

9. Transverse joints should be staggered.

   Where two or more layers of bituminous material are to be paver laid, care must be taken to ensure that transverse joints in successive layers do not coincide. Transverse joints in upper and lower layers should have a minimum offset of 2 metres. Similarly, transverse joints between two adjoining paver lanes should have a minimum offset of 2 metres.

10. Daily work output should be planned in such a way that the number of joints required is kept to a minimum.

11. If the newly constructed layer, containing the transverse joint, is to be used by traffic within 36 hrs, a ramp of full lane width made up of hot or cold mix material should be constructed with a slope of 1: 20 if the design speed of the traffic on the road is more than 75 km per hour and with at least a slope of 1: 10 if the design speed is less than 75 kmph.

    Suitable cautionary signs and lights should be placed before the occurrence of such a joint.

    On resumption of work, the material for the ramp should be removed and discarded, and may not be re-used on the site.

12. In general, transverse joints are perpendicular to the alignment of the carriageway. However, sometime slightly skewed (6:1) joints are provided but only in the binder and the wearing courses.

13. In all cases of joint construction the following points should be borne in mind:

    (i) Joint faces should be sprayed or painted with a thin but uniform coat of bitumen (suitable emulsion paint may also be used) before fresh mix is allowed to be placed against it.

    (ii) The paver screed should be properly heated prior to laying of the mixture.

    (iii) The joint line should not be irregular and must be true to joint alignment.

(b) Longitudinal Joint

1. Longitudinal joints in all courses should not be located along the same line.

   On the top surface the joint will normally be along the centre-line for a two-lane carriageway and along the lane edge for multi-lane carriageways.

   For all previous layers under the top layer the joint location should be shifted by at least'.150 mm from any other layer.

2. Locating joint offsets may present a problem, and, therefore, an overall plan for all joints must be made before commencement of work on the lowest bituminous course.

3. Joint should be parallel to the alignment of the carriageway centre-line.

4. Joint must have a vertical face.

5. Joint faces should be sprayed or painted with a thin but uniform coat of bitumen (suitable emulsion paint may also be used) before fresh mix is placed.

6. The longitudinal joint may be rolled directly behind the paving operation.

7. The correctness of lane alignment is critical to the success of longitudinal joint formation. Therefore, it is essential that the first lane material placed by paver is absolutely true to the alignment (paver travel controlled by string line or electronic guidelines).

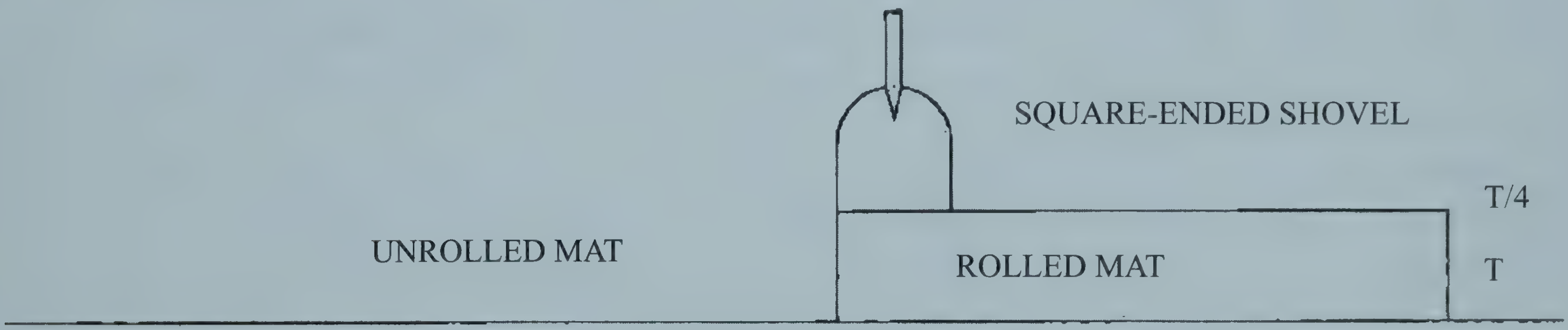
8. If the joint alignment adjacent to further work has been broken or damaged by traffic or for any other reason, the edge-line should first be corrected (by straight edge or string line) and trimmed before commencing fresh paving or rolling operation.

9. While spreading the material along the joint the paver should be run in such a manner that the materi overlaps 25 to 50 mm onto the previously laid lane beyond the vertical face of the joint as shown in Fig 8.21 (a).

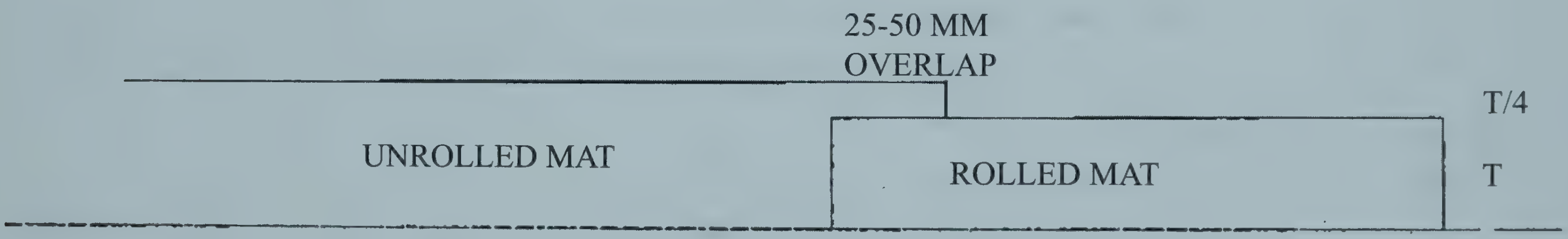
Care must be taken to see that the depth of fresh material over the previously laid surface is uniform so as not to create a rough or irregular joint after compaction. The thickness of overlap material should be approximately a quarter of the final compacted thickness of the mat or as indicated by the screed setting of the paver for loose material in the new lane to be laid.

From the material overlapping the cold joint, the coarse aggregate should be carefully removed. In case another layer is to be provided over and above the layer being spread, the excess coarse aggregate at the joint may be distributed over the unrolled lane with the help of a broom. The overlapping material is then dragged back to the hot lane so that the roller can press the small excess into the hot side of the joint.

A 'trimmed joint' can also be made as shown in Fig. 8.21 (b) by removing, with the help of a square ended shovel all freshly placed material that has overlapped the already rolled mat.



(a) Making a Trimmed Joint



(b) Providing Overlap of Adjoining Lane

Fig. 8.21. Construction of Longitudinal Joint

8.4.5. Rolling operations

8.4.5.1. Introduction : Rolling is a highly technical and skilful operation during which poor judgement is likely to result in failure to achieve the required compaction. Although, various guidelines describing sound engineering practices for compaction procedures are available each case will have unique features and there can be no substitute for experience in achieving successful compaction.

8.4.5.2. Temperature : Temperature is an extremely important factor in compaction of bituminous mixes. While the temperature during laying and for rolling may be specified, in reality, during construction, there may be significant temperature variations throughout the thickness of a single layer of bituminous mixture. The bottom of the layer, in contact with the old surface, and the top of the layer, exposed to the atmosphere and in contact with roller wheels and the water applied to them to prevent sticking, soon lose heat, while the middle portion of the layer may retain its temperature for quite some time. Trial runs are likely to be the best guide for the ideal time to commence rolling.

8.4.5.3. Planning of rolling operations : The pace at which the rollers should work is determined various factors, like,

- the rate of supply of material,
- the thickness of the mat,
- the speed at which the paver is laying the mat,
- the length of rolling zone, and
- the number of rollers deployed on the job.

The need for quick and efficient rolling may be more acute with thin layers which lose heat quickly rather than on thick layers which may retain heat and remain in plastic condition for a longer duration. Thus, rolling full-depth base lifts may, sometimes, offer a longer time-scale than thin surfacing for which prompt action is essential.

8.4.5.4. Test strips : There are three distinct phases relating to asphalt production and laying, each with equal importance. It is essential that the Specification is written to accommodate these phases.

First is the "Laboratory job mix design" phase. Once this is approved, the Contractor has to demonstrate that (second phase) his hot-mix plant can make this mix within tolerances specified. This is the "Plant Trial" phase. The last of the three phases is, if the plant trials are successful, that the Contractor must demonstrate that he is able to lay the material and compact it successfully. This phase (third) is known as "Laying Trials".

Laying trials should be conducted off road, on a base equally as firm as the road laying conditions, and with the same paver, laying crew, and compaction equipment. Cores taken from the laying trial are tested for density, and if this meets the specified percentage of the Marshall "cake", then the mix can be approved, on condition that the machines and work people do not change.

If a machine breaks down and is substituted with a different type/weight of machine, then technically another laying trial should be conducted.

Laying trials should normally be held not less than three days prior to actual work, on a test laying area 30 m to 60 m in length of the same thickness as the design and of a width to allow at least three parallel rolling zones for the roller. It is essential that the material underlying the trial area should behave in a similar manner to the materials over which the bituminous mixture is to be laid in practice. This often means that it is necessary to construct special sections of the sub-base and base on which to perform the trials. It is of little value to establish rolling patterns which will achieve acceptable densities if the same process will not give acceptable layer thickness, surface tolerances or the required finish.

Among the many useful pieces of information that should be obtained from trials are the speeds that are necessary for the rollers to keep pace with the paver and the supply of material and the number of passes required to achieve the specified density. It must be kept in mind that each type of roller has an optimum top speed for efficient compaction.

8.4.5.5. Estimation of roller requirement : From an indication of the speed of operation and the number of roller passes necessary, approximate assessment can be made about the number of rollers to be deployed on the job and the rolling pattern to be followed.

The roller requirement can be calculated by surface area capacity or by volume (or tonnage capacity of the roller).

If,

N_A = number of rollers required on surface area basis,

N_V = number or rollers required on volume basis,

a = total surface area in sq. metres to be rolled per hour,

v = total volume in cubic metres to be rolled per hour,

p = number of passes required,

w = width of drum in metres,

s = speed of roller in metres per hour, and

e = efficiency factor for roller working

then,
$$N_A = \frac{a * p}{s * w * e}$$

$$N_v = \frac{v * p}{s * w * e}$$

Efficiency factor is the ratio of net practical capacity of the roller to its theoretical capacity. It is always less than '1' as the rolling time and effort spent on overlap, lane changes, reversing and run on compacted pavement for joint compaction, etc. are required to be deducted from actual application. Experience suggests that 'e' should be taken as 0.5 to 0.6 for bituminous work.

For all large size project work there should be a suitable number of stand-by machines to guard against mechanical failure.

8.4.5.6. Rolling sequence : Rolling is generally carried out in accordance with the following sequence:

(a) transverse joint,
(b) longitudinal joint,
(c) (lower) edge rolling,
(d) break-down rolling,
(e) intermediate rolling, and
(f) finish rolling or polishing

Each of the above factors is dealt with below in that order:

(a) Transverse Joint (Day Joint)

Rolling should start with the roller first moving along the already compacted longitudinal joint with the adjacent length for some length towards the transverse joint, then the joint rolling commenced transversely (Fig. 8.22 a) from the corner of the transverse joint with the longitudinal joint with almost the entire roller being on the mat compacted earlier except about 150 mm of the drum width of a rear wheel (in case of a three-wheeled roller) on the new material.

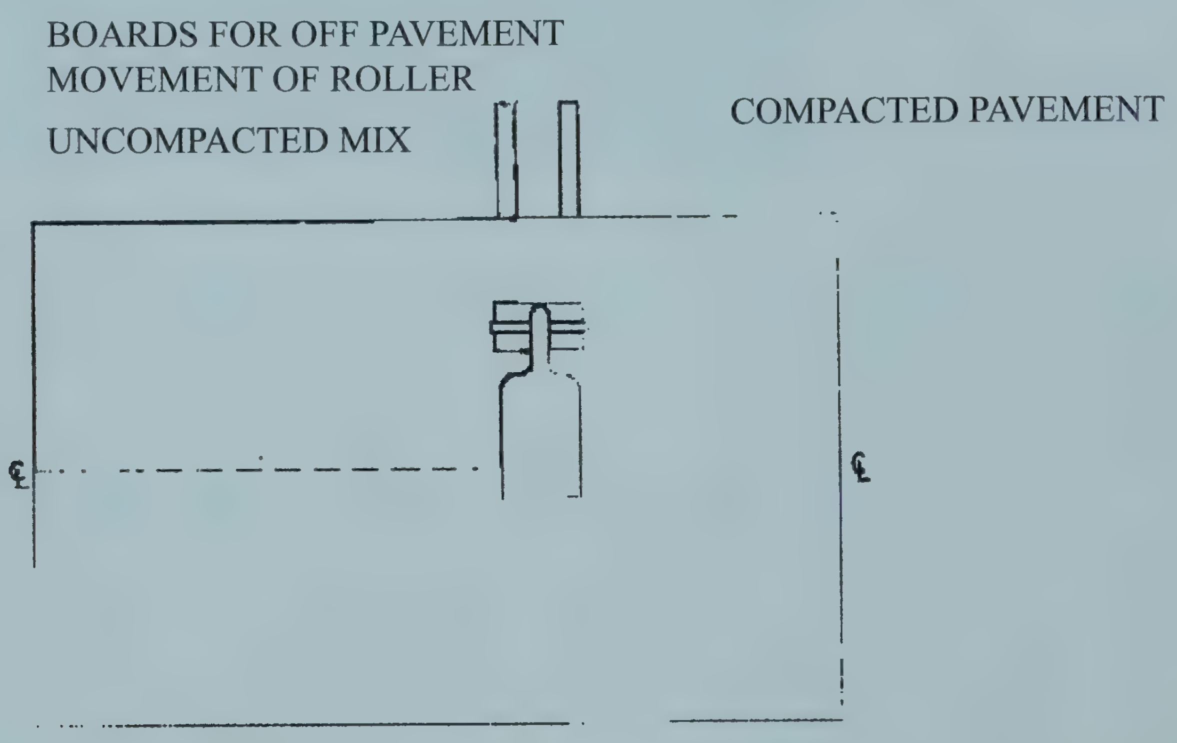
The successive passes should cover about 150 mm to 175 mm of additional fresh material in case of a tandem roller and half-width of a rear wheel for the three-wheeled roller till the entire width of the drive roll is on the fresh mix.

Timber or steel plate boards of thickness equal to the mat should be placed at the pavement edge so that the roller can move on to them after reaching the edge.

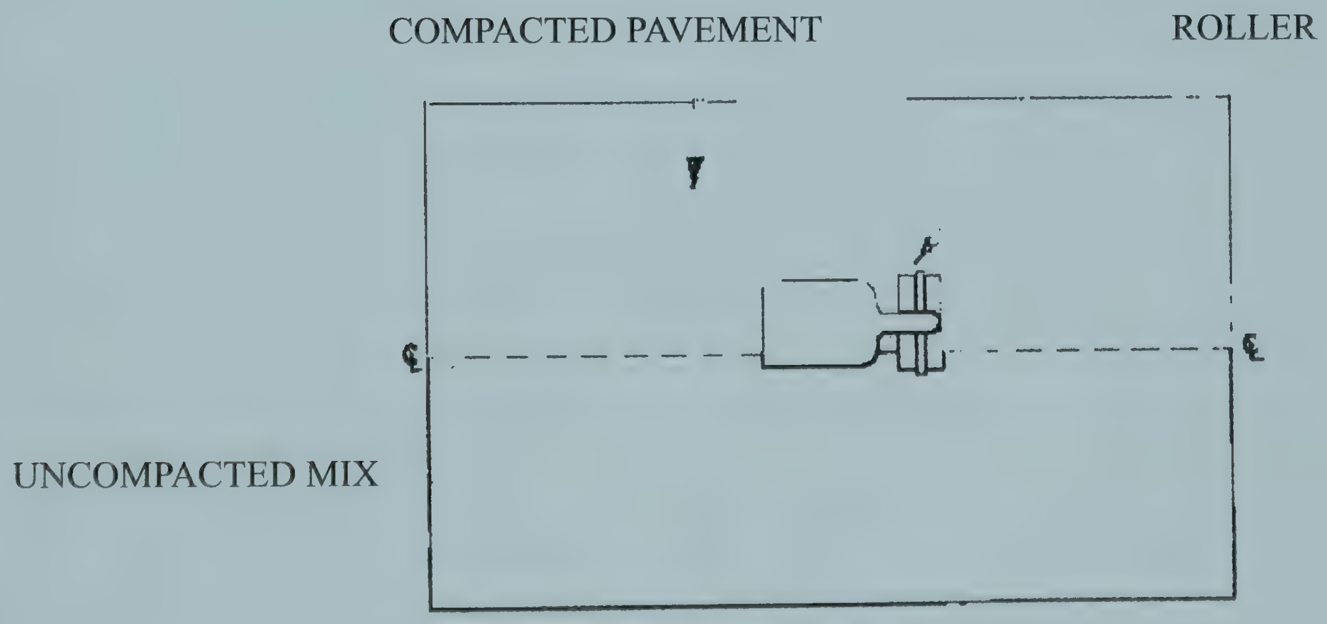
(b) Longitudinal Joint

There are two generally accepted rolling patterns used for compaction of longitudinal joints.

One is to position almost the entire width of the roller on the previously compacted lane (Fig. 8.22 b) excepting about 50 mm of the drive roll (rear roll in case of three-wheeled roller) which should be on the freshly placed mixture and then in successive passes cover greater width on the uncompacted material progressing, by150 mm to 175 mm in case of tandem roller or by half-width of drive roll in case of a three-wheeled roller to cover the joint completely by the full width of drive wheel.



(a) Rolling a Transverse Joint



(b) Rolling a Longitudinal Joint

Fig. 8.22. Rolling Transverse and Longitudinal Joints

In the alternative method the roller is positioned almost entirely on the new mix with only 100 mm to 150 mm of the width of the drum on the previously compacted lane. The roller should continue compaction until the joint is completely compacted and the overlap material, placed on the previously laid lane, has been fully pressed into the old surface and the joint.

Although, both the procedures described above are accepted as standard practice, the former is considered preferable.

In case of multiple pavers operating in echelon (laying parallel lanes side by side) no overlap of material is necessary but care must be taken to ensure that the loose material in adjacent lanes abuts exactly without any gap.

In such cases also all the longitudinal joints should be rolled prior to the compaction of other areas of spread material.

Construction planning should ensure, to the extent practicable, that adjacent lanes are constructed on the same day so that no unmatched length of lane is left for the next day.

Where leaving an unmatched longitudinal lane becomes unavoidable and when the road is to be used by traffic within 36 hrs, the vertical side edge should be provided with a short support ramp with not less than 1:5 slope and suitable cautionary signs and lights placed on the road sufficiently in advance to ensure public safety.

(c) Edge Rolling

Immediately, after the longitudinal joint (and concurrently with it when sufficient numbers of rollers are available) the lower edge should be rolled.

Before compacting the material the edge should be suitably butted or supported by timber boards or similar material approximately 'equal in thickness to the expected compacted thickness of the layer, so that the roller can begin work right at the lane edge, without causing excessive distortion of the layer edge.

(d) Breakdown Rolling

1. Lane rolling must start with breakdown rolling. This should be carried out by smooth-wheeled rollers of adequate weight. The three-wheeled roller was extensively used in the past with satisfactory performance. But with the advent of vibratory rollers now, the preferred method is to use a tandem vibratory roller in static mode initially to press the mat. Once the mat is pressed down, the vibratory mode can be switched on. A desirable practice is to position the roller such that the heavier drum is near the paver.

   A static 8 to 10 tonne tandem wheel roller can also be deployed for breakdown rolling, provided the specified density is achieved: Breakdown rolling must achieve the majority of the required compaction at the first application. An ineffective first pass may make the final compaction significantly more difficult to achieve.

2. The weight of the break-down roller required for a particular layer will depend on a number of factors, including the final density required, the layer thickness and the constitution of the mixture, but steel-wheeled rollers of 8 to 12 tonne are generally considered necessary.

3. Compaction is effected primarily by imparting vertical movement to the aggregates and other materials through the roller load. However, if this is accompanied by excessive horizontal movement the purpose will be defeated.

   Horizontal displacement will cause heaving of the material all around the point of loading and will generally be manifested by a "crawling" of the mixture ahead of the roller and formation of ridges on both sides of the roller in the transverse direction. This leads to compaction in varying thickness and therefore leaving an uneven final surface after compaction.

   Where this occurs, it may be necessary to allow the material to cool a little (to a temperature sometimes referred to as the "breakdown temperature") in order to develop greater internal resistance.

   With repeated passes of the roller the paving Mixture will continue to settle until the resistance of the mix aggregated over the total area of contact equals that to support the wheel load. Although, a low temperature will increase the resistance and prevent horizontal displacement, it will also inhibit vertical movement of the material and therefore will tend to reduce the amount of compaction achieved.

   Only a suitable combination of temperature, stability and material content in the thickness of the layer will lead to satisfactory compaction. It is very much a matter of experience supplemented by actual observations during trials.

4. It is very important to commend breakdown rolling (Fig. 8.23) soon after laying and in any case complete it before the temperature cools down below the rolling temperature indicated in Table 8.3. If the temperature of the mix falls below the stipulated minimum temperature, the mix should be rejected.

   Compaction helps in retaining heat. Once initial rolling is started heat loss reduces - this is another reason why initial compaction should be carried out as soon as possible.

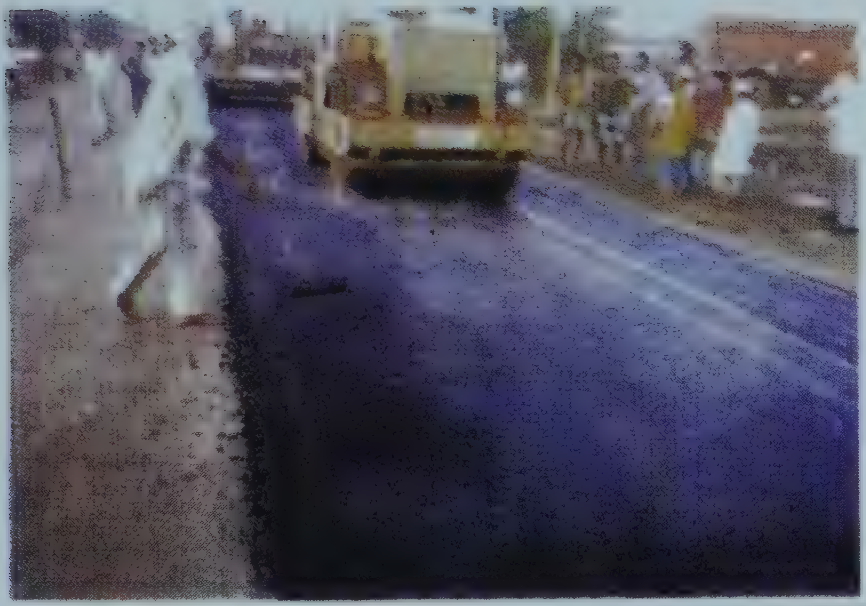


Fig. 8.23. Break-down Rolling in Progress

5. It is important that, while carrying out break-down rolling, the roller moves with the drive wheel forward in the direction of travel. The greater linear load of the drive wheel imparts larger load and the turning force in the drive wheel tends to pack the material under the wheel, thus, achieving more effective compaction.

   If a vibrating tandem roller is used the vibrating roll should be towards the Paver, and first two passes (forward and back), for the full width of the lane, should be without vibration.

6. Rolling pattern

   By this stage it is necessary to have decided upon the rolling pattern to be followed. This is done after assessing the speed of the paver, the length of spread and the total width of lane or lanes to be covered. Then the length of the actual rolling zone is fixed, which will generally be of the order of 50 m.

   Generally, parallel rolling zones are used for compaction, a zone consists of a section of the width of the material to be compacted, each zone being less than the width of the roller to be used.

   Starting from the outside lane the roller advances along the paved material upto the end of the selected zone, with the drive wheel forward and again, along exactly the same wheelpath, returns back to the starting point. It then changes lane, to the next zone, by overlapping the first rolled lane by 150 mm in case of tandem roller or by half-width of rear wheel in case of three-wheeled roller and proceeds again as before.

   The changes of lane should always be undertaken on the fully compacted pavement or on a portion of the pavement which has received at least some of its final compaction.

   The change in direction of travel (reversal) on the paver end should be progressively staggered for each zone (at least by 1 metre) so that if any ridge is created by reversal this does not become continuous. The rolling pattern is shown in Fig 8.24.

   After all the three rolling zones have been so covered by at least two passes the roller again moves on to the outer edge in its original position, where the material has by now slightly cooled to repeat the operation till the design number of passes are achieved over the entire width. Least interference to traffic should be ensured.

(e) Intermediate Rolling

1. Intermediate rolling should be started immediately after breakdown rolling is complete when the mix has not lost much of heat and is still in a plastic or compatible state.

   Pneumatic Tyred Rollers (PTR) of 12 to 15 tonnes weight are considered suitable. Tandem vibratory rollers of static weight 8 or 10 tonnes may also be used, when specified, or after demonstration of their effectiveness in a trial.

2. The intermediate rolling by pneumatic rollers may not lead to substantive increase in density but it does increase the stability of the mix by kneading and re-orientation of the particles, an effect similar to long duration exposure to rubber tyred trucks on roads, ensuring minimum distortion under further wheel-loads.

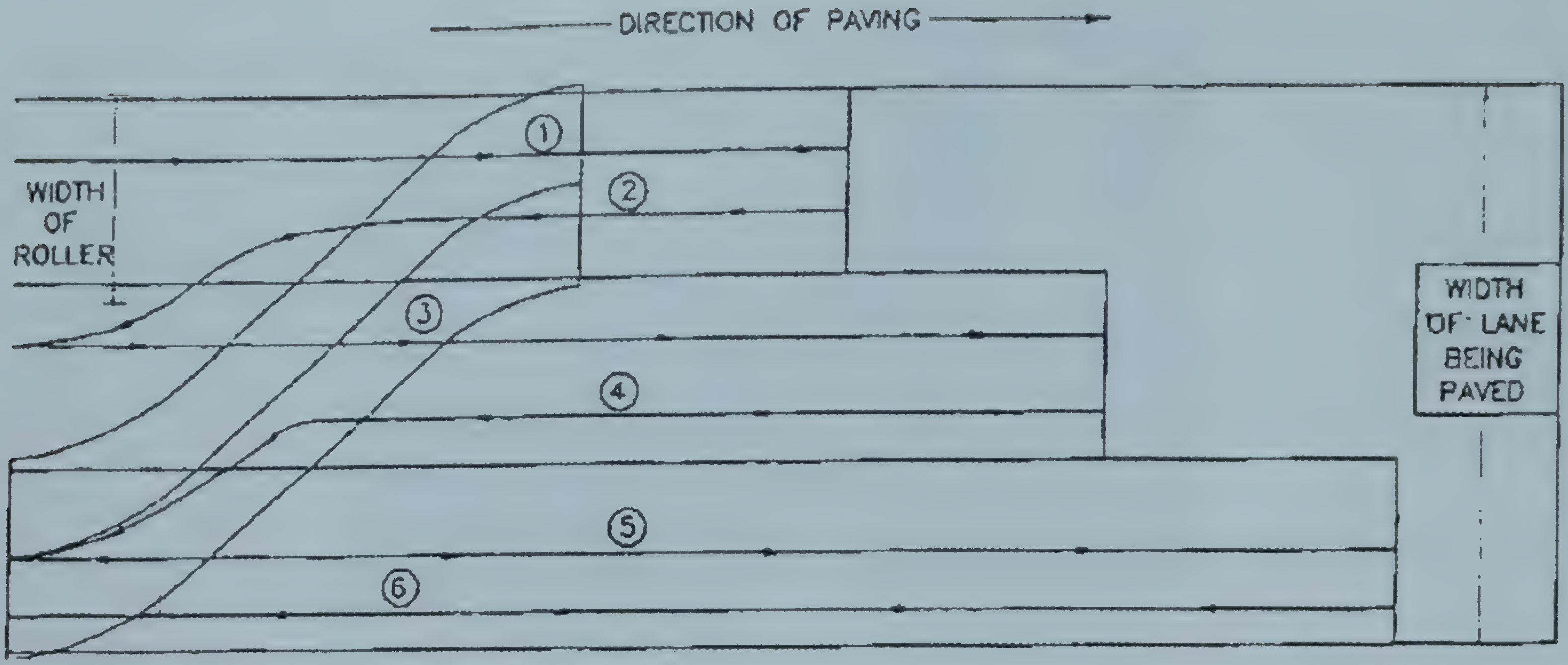


Fig. 8.24. Rolling Pattern

3. The use of pneumatic rollers (Fig 8.25) ensures a more even load distribution over the road surface and leads to equal and uniform compaction, unlike steel-wheeled rollers, and also less heat loss occurs in contact with the tyres.

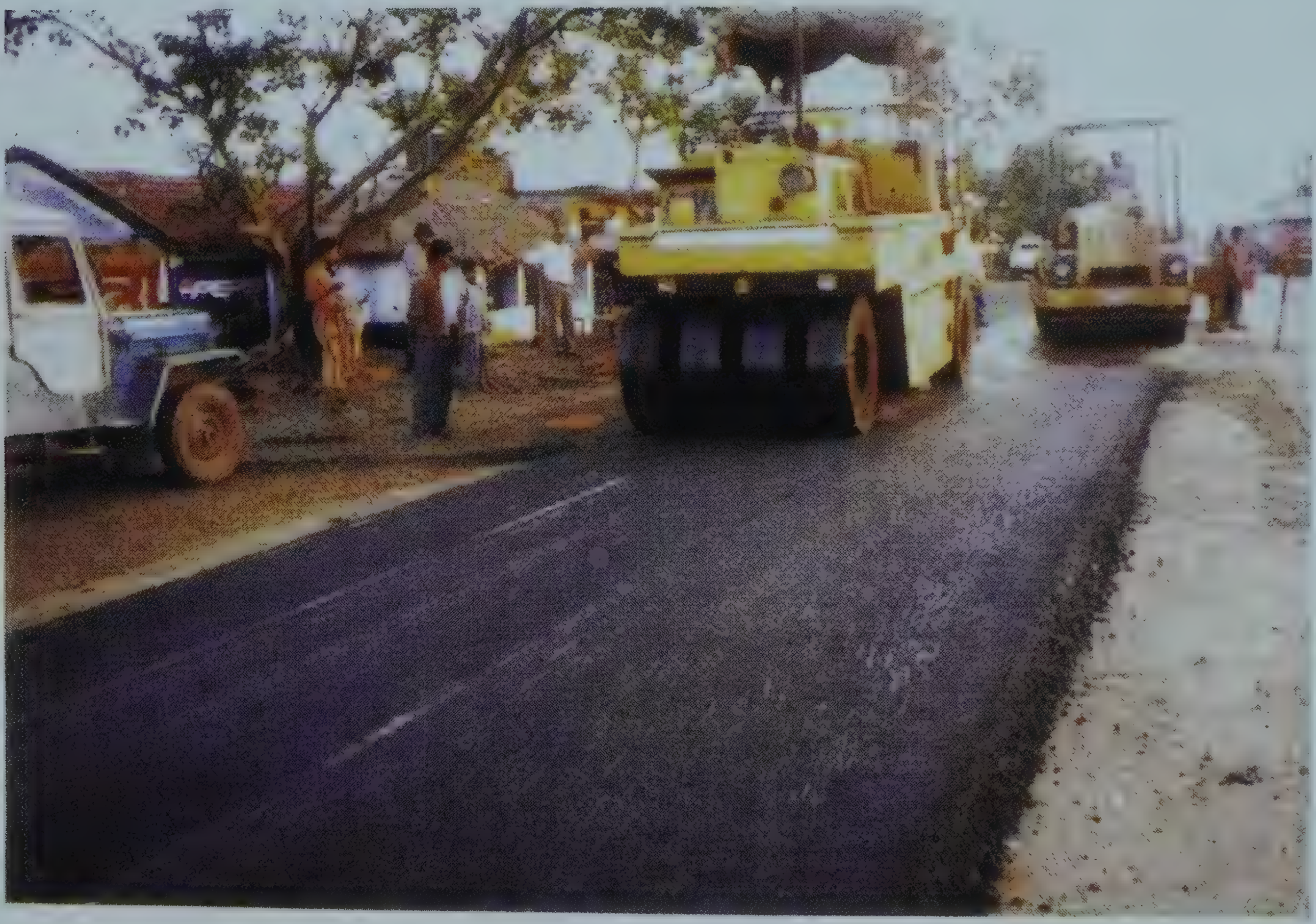


Fig. 8.25. Rolling in Progress with Pneumatic Tyred Roller

4. The intermediate rolling provides the surface with a sealing effect which increases imperviousness of the surface.
5. The tyre pressure during rolling should be as high as possible (0.7 to 0.9 MPa is considered adequate) provided it does not lead to lateral displacement.
6. Since the final rolling will not contribute anything to further compaction, the intermediate rolling should be continued until the minimum specified density is achieved. (This may conveniently be checked, approximately, by the use of a suitably calibrated nuclear density gauge).
7. A rolling pattern generally similar to that used for breakdown rolling should be used for intermediate rolling.

(f) Finish Rolling

Final or finish rolling, where necessary, may be provided by the use of a two or three-axled steel-wheeled roller (with the vibration switched off).

Finish rolling is provided while the material is still warm and at least malleable enough for removal of tyre marks or indentations left by the PTR.

Finish rolling may not be required on all surfaces. Only the top wearing surface and sometimes the binder may require finish rolling.

Excessive finish rolling specially on mats with harsh mixes may induce the surface with appearance of fine hair-cracks.

8.4.5.7. Compaction of difficult mixes

(a) Harsh Mixes

The search of more and more effective load bearing material to match the increase in wheel loads on highways, has led to bituminous mixtures for use in high traffic intensity corridors, tending towards the use of harsh mixtures. In general, the strength of a mix increases with increasing aggregate sizes, increasing proportion of aggregate in the mix and increasing hardness of bitumen (or decreasing penetration value).

The compaction of these mixes needs the use of 8 to 12 tonne rollers. Use of vibratory rollers in the intermediate stage is also considered helpful.

(b) Tender Mixes

Tender mixes are mixtures with relatively low resistance to deformation. There may be various causes for tender mixes including

- Mix design imbalance,
- Low air voids resulting from mix component fluctuations during production,
- Excess use of middle grade sand,
- Less fines (minus 75 micron material),
- Use of very soft grade of bitumen, and
- Remnant moisture in mix acting as lubricant.

Compaction of such mixes is difficult and is generally accompanied by excessive horizontal displacement. During the process of densification the wheel surface of the roller and the receiving bed of the lower course provide the upper and lower confines but the lateral confines and actual resistance to volume reduction consists of stability of the mix through inter-particle friction and cohesion provided by the binder.

Once the mix has been made and no change can be made in the aggregate content and grade of bitumen used, there are only two courses open:

- One is to allow the mix to cool sufficiently to increase the viscosity of the bitumen and evolve resistance to roller pressure, and
- the other is either to off-load the ballast of the roller in use or use a lighter roller, whose load the mix can tolerate.

The latter solution may not always be satisfactory as it may fail to attain adequate volume reduction and density.

Generally, mixtures with a tendency to be tender should be redesigned.

8.4.5.8. General precautions for rolling : Listed below are the more important points to be considered which should improve results achieved during compaction:

(i) A steady and uniform speed will always give good performance in rolling.

(ii) The roller should be continuously on the move and never allowed to stand on the mat being compacted or even on a newly compacted surface.

(iii) Any roller, especially a vibrating one should not be left parked on an uncompacted bituminous surface.

(iv) Jerky starts, sudden braking and sharp changes in direction should not be made while rolling.

(v) Change of lane should be made only when on an already compacted surface.

(vi) Except on transverse joints and in small undefined areas, rolling should always take place in a longitudinal direction.

(vii) In areas inaccessible to rollers small compactors or vibrating mechanical hand held tampers may be used.

It should be borne in mind that contact of the mat with steel-wheels is one cause for heat loss in the mat material and sprinkling of water (to prevent pickup) may add to this loss.

(viii) Pneumatic tyred rollers also cause heat loss and, when the tyres are still cold, they tend to pickup material from the surface.

Use of a wetting pad or application of a small amount of detergent to the tyres may be made until the tyres warm up in contact with the hot bituminous mixture. A thin application of vegetable (cooking) oil is also effective.

Oils detrimental to bituminous surfaces or excess of water must not be used.

(ix) After rolling, the surface should be inspected for patches of loose material, broken edges, materials mixed with dirt or other deficiencies. Such materials must be removed and replaced with fresh hot mix recompacted to merge with the surrounding area in density and smoothness.

8.4.6. Bituminous macadam (Clause 504 of Ministry's Specifications)

8.4.6.1. Weather and seasonal limitations : Laying should be suspended while free-standing water is present on the surface to be covered. Laying should be avoided as far as is practicable during rain, fog and dust storms, and if these conditions threaten to be prolonged laying should be suspended. Laying of bituminous mixtures should not be carried out when the air temperature at the surface on which it is to be laid is, below 10°C or when the wind speed at any temperature exceeds 40 km/hr at 2 m height unless specifically approved, and then only provided that rolling can be completed before the mixture cools below the specified minimum compaction temperature for the mixtures.

8.4.6.2. Preparation of the base : The base on which bituminous macadam is to be laid should be prepared, shaped and conditioned to the required profile and a priming coat where needed should be applied in accordance with para 8.3.1.

8.4.6.3. Tack coat : A tack coat should be applied over the base, where required para 8:3.2 gives the details.

8.4.6.4. Preparation and transportation of the mixture : These have been described in paras 8.4.2 and 8.4.3.

8.4.6.5. Spreading : Para 8.4.4 applies here. Mixing should be accomplished at the lowest temperature and in the shortest time that will produce a mixture with complete coating of the aggregate and at a suitable temperature to ensure proper compaction. The ideal mixing and compaction temperatures for the particular bitumen in use should be obtained from the Bitumen Test Data Chart and should correspond to a viscosity of 2 Poise (0.2 Pas.) and 3 Poise (0.3 Pas.) respectively, based on the original (un-aged) bitumen properties. For guidance, the ranges of acceptable mixing and rolling temperatures for some typical penetration grade bitumens are shown in Table 8.3.

8.4.6.6. Rolling : Para 8.4.5 applies here. Generally, the initial or breakdown rolling should be done with 8 to 10 tonnes dead weight smooth-wheeled rollers. The intermediate rolling should be done with 8 to 10 tonnes dead weight or vibratory rollers or with a pneumatic tyred roller of 12 to 15 tonnes weight having a tyre pressure of at least 0.7 MPa. The finish rolling should be done with 10 to 12 tonnes weight smooth wheeled tandem rollers.

Table 8.3. Manufacturing and Rolling Temperatures

Penetration Bitumen	Bitumen Mixing (°C)	Aggregate Mixing (°C)	Mixed Material (°C)	Rolling (°C)	Laying (°C)
35	160-170	160-175	170 Maximum	100 Minimum	130 Minimum
65	150-165	150-170	165 Maximum	90 Minimum	125 Minimum
90	140-160	140-165	155 Maximum	80 Minimum	115 Minimum

Note :The difference in temperatures of aggregate and bitumen should not exceed 14°C.

Rolling should be continued until the density achieved is a minimum of 91 per cent of Percentage Refusal Density (PRD). The required frequency of testing is defined in Chapter 10. If the density criterion according to Marshall specimen is specified the rolling should be continued till the entire surface has been rolled to 95 per cent of the average laboratory density.

8.4.6.7. Surface finish and quality control of work : The surface finish of the completed construction should conform to the requirements set out in Chapter 10.

8.4.6.8. Protection of the layer : The bituminous macadam should be covered with either the next pavement course or wearing course, as the case may be within one or two days. If there is to be any delay, the course should be covered by a seal coat before allowing any traffic over it.

8.4.6.9. Arrangements for traffic : During the period of construction, arrangements for traffic should be made in accordance with para 8.2.3.

8.4.7. Dense-graded bituminous material (Clauses 507, 508 and 509 of Ministry's Specifications)

8.4.7.1. Weather and seasonal limitations : Laying should be suspended while free-standing water is present on the surface to be covered. Laying should be avoided as far as is practicable during rain, fog and dust storms, and if these conditions threaten to be prolonged laying should be suspended. Laying of bituminous mixtures should not be carried out when the air temperature at the surface on which it is to be laid is below 10°C or when the wind speed at any temperature exceeds 40 km/hr at 2 m height unless specifically approved, and then only provided that rolling can be completed before the mixture cools below the specified minimum compaction temperature for the mixtures.

8.4.7.2. Preparation of the base : The base on which Dense Graded Bituminous Material is to be laid should be prepared, shaped and conditioned to the profile required for the particular layer. The surface should be thoroughly swept free of dust and foreign matter using a mechanical broom, and the dust removed or blown off by compressed air. In locations where mechanical means cannot reach, other approved methods should be used. A priming coat, where needed, should be applied in accordance with para 8.3.1.

8.4.7.3. Tack coat : A tack coat over the base should be applied where needed in accordance with para 8.3.2. Tack coat is only required where the prime coat has been exposed to traffic.

8.4.7.4. Preparation and transportation of the mixture : This has been fully described in paras 8.4.2 and 8.4.3.

8.4.7.5. Spreading : Mixing should be accomplished at the lowest temperature and in the shortest time that will produce a mixture with complete coating of the aggregate and at a suitable temperature to ensure proper compaction. The ideal mixing and compaction temperatures of the particular bitumen should be obtained from the Bitumen Test Data Chart and should correspond to a viscosity of 2 Poise (0.2 Pas.) and 3 Poise (0.3 Pas.)

respectively, based on the original (unaged) bitumen properties. For guidance, the ranges of acceptable mixing and rolling temperatures for some typical penetration grade bitumens are shown in Table 8.3.

8.4.7.6. Rolling : Generally, the initial or breakdown rolling should be done with 8 to 10 tonnes dead weight smooth-wheeled rollers. The intermediate rolling should be with a pneumatic tyred roller of 12 to 15 tonnes weight having a tyre pressure of at least 0.7 MPa. The inclusion of pneumatic-tyred rollers should be mandatory. The finish rolling should be done with 12 to 15 tonnes dead weight smooth wheeled tandem or three drum roller. The exact pattern of rolling should be established at the laying trials.

Rolling should commence at the edges and progress towards the centre longitudinally except that on superelevated and unidirectional cambered portions, it should progress from the lower to the upper edge parallel to the centre line of the pavement.

Rolling should be continued until the specified density achieved typically a minimum of 93 per cent and a mean value of 95 per cent of Percentage Refusal Density (PRD). For Marshall asphalt, a density of 98 per cent of the average laboratory density is often specified for wearing course, and 95 per cent for basecourse. The required frequency of testing is defined in Chapter 10.

8.4.7.7. Job mix formula : The job mix formula proposed for use in the works should give the following details:

(i) Source and location of all materials;
(ii) Proportions of all materials expressed as follows where each is applicable;
    (a) Binder as percentage by weight of total mixture;
    (b) Coarse aggregate/Fine aggregate/Mineral filler as percentage by weight of total aggregate including mineral filler;
(iii) A single definite percentage passing each sieve for the mixed aggregate;
(iv) The results of tests enumerated in Tables 4.11, 4.14 and 4.16;
(v) Test results of physical characteristics of aggregates to be used;
(vi) Mixing temperature and compacting temperature.

While establishing the job mix formula, it must be ensured that it is based on a correct and truly representative sample of the materials that will actually be used in the work and that the mixture and its different ingredients satisfy the physical and strength requirements.

If any change in the source of materials is proposed, a new job mix formula should be established before actually using the materials. Plant and laying trials must be carried out with each change of the job mix.

8.4.7.8. Permissible variation from job mix formula : The permissible variations from the job mix formula are as under: -

Description	Permissible variation	
	Base/binder course	Wearing course
Aggregate passing 19 mm sieve or larger	± 8%	± 7%
Aggregate passing 13.2 mm, 9.5 mm	± 7%	± 6%
Aggregate passing 4.75 mm	+ 6%	± 5%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	± 5%	± 4%
Aggregate passing 0.3 mm, 0.15 mm	± 4%	± 3%
Aggregate passing 0.075 mm	± 2% ±	± 1.5%
Binder content	+ 0.3%	± 0.3%
Mixing temperature	± 10°C	± 10°C

8.4.7.9. Opening to traffic : Traffic may be allowed after completion of the final rolling when the temperature of the asphalt layer at the mid-depth of the completed layer has cooled to the daytime maximum ambient temperature. When daytime maximum ambient temperatures are in excess of 35°C, great care is needed to ensure that this criterion is met, particularly where slow moving heavy traffic is involved. It is preferable to allow at least 24 hrs. if possible 36 hrs., before allowing traffic to run on the surface.

8.4.8. Open-graded premix surfacing (using bitumen) (Clause 511 of Ministry's Specifications)

8.4.8.1. Weather and seasonal limitations : Laying should be suspended while free-standing water is present on the surface to be covered. Laying should be avoided during rain, fog and dust storms. Laying of bituminous mixtures should not be carried out when the air temperature at the surface on which it is to be laid is below 10°C or when the wind speed at any temperature exceeds 40 km/hr at 2 m height unless specifically approved, and then only provided that rolling can be completed before the mixture cools below the specified minimum compaction temperature of the mixture.

8.4.8.2. Preparation of base : The underlying base on which the bituminous surfacing is to be laid should be prepared, shaped and conditioned to the specified lines, grade and cross-section. A prime coat where needed should be applied in accordance with para 8.3.1.

8.4.8.3. Tack coat : A tack coat complying with para 8.3.2 should be applied over the base preparatory to laying of the surfacing, if the prime coat has been openend to traffic, or has become contaminated in any other way, say by flooding, or dust storm.

8.4.8.4. Preparation of premix : Hot mix plant of appropriate capacity and type should be used for preparation of the mix material. The hot mix plant should have a separate dryer arrangement for heating aggregate.

For guidance, the ranges of acceptable mixing and rolling temperatures for some typical penetration grades of bitumen are shown in Table 8.3.

The mix should be immediately transported from the mixer to the point of use in suitable vehicles or wheel barrows. The vehicles employed for transport should be clean and the mix being transported covered in transit.

8.4.8.5. Spreading and rolling : The pre-mixed material should be spread by suitable means to the desired thickness, grades and crossfall (camber) making due allowances for any extra quantity required to fill up depressions, if any. The crossfall should be checked by means of camber boards and inequalities evened out. Excessive use of blades or rakes should be avoided. As soon as sufficient length of bituminous material has been laid, rolling should commence with an 8 to 10 tonne roller, preferably of smooth wheel three point, or tandem type, or other approved equipment. Rolling should begin at the edge and progress toward the centre longitudinally, except that on superelevated and uni-directional cambered portions, it should progress from, the lower to upper edge parallel to the centre line of the pavement.

When the roller has passed over the whole area once, any high spots or depressions which become apparent should be corrected by removing or adding premixed materials. Rolling should then be continued until the entire surface has been rolled and all the roller marks eliminated. In each pass of the roller the preceding track should be overlapped uniformly by at least 1/3 width. The roller wheels should be kept damp to prevent the premix from adhering to the wheels. In no case should fuel/lubricating oil be used for this purpose although a thin coating of vegetable (cooking) oil may be used. Excess use of water for this purpose should be avoided.

Rollers should not stand on newly laid material while there is a risk that it will be deformed thereby. Rolling operations should be completed in every respect before the temperature of the mix falls below 100°C. Joints along and transverse to the surfacing laid and compacted earlier should be cut to their full depth so as to expose fresh surface which should be painted with thin coat of appropriate binder before the new mix is placed against it.

8.4.9. Open-graded premix surfacing (using cationic bituminous emulsion) (Clause 511 Ministry's Specification)

8.4.9.1. Weather and seasonal limitations : Laying should be suspended while free-standing water is present on the surface to be covered. Laying should be avoided during rain, fog and dust storms, and if these conditions threaten laying should be suspended. Laying of bituminous mixtures should not be carried out when the air temperature at the surface on which it is to be laid is below 10°C or when the wind speed at any temperature exceeds 40 km/hr at 2 m height unless specifically approved, and then only provided that rolling can be completed before the mixture cools below the specified minimum compaction temperature for the mixture.

8.4.9.2. Preparation of the base : The underlying base on which the premix surfacing is to be laid should be prepared, shaped and conditioned to the specified lines, grades and cross sections. A prime coat where needed should be applied in accordance with para 8.3.1.

8.4.9.3. Preparation of binder : Before opening, the cationic bitumen emulsion drums should be rolled at low speed, to and for, 5 to 6 times, for a distance of about 10 metres, to mix the contents properly.

8.4.9.4. Tack coat : A tack coat complying with para 8.3.2 should be applied over the base preparatory to laying of the surfacing.

8.4.9.5. Preparation of premix : Premixing cationic bitumen emulsion and aggregates can be done in a suitable mixer such as a cold mixing plant as per IS:5435 (Revised) or concrete mixer or by shovels in exceptional cases for minor work. However, for large works, continuous mixing operation can be done either in batch or continuous mixer units suitable for emulsion mixes.

When using concrete mixer for preparing the premix, 0.135 cum (0.09 cum of 13.2 mm size and 0.045 cum of 11.2 mm size) of aggregates per batch, may be used as this quantity will cover 5 sqm of road surface with 20 mm average thickness.

The aggregates required for one batch should be stockpiled near the mixer.

First the coarse aggregates of 13.2 mm size should be charged into the mixer followed by 5 to 6.5 kg of cationic bitumen emulsion and then the 11.2 mm size aggregate is added followed by 5 to 6.5 kg of cationic bitumen emulsion. After the materials have been mixed thoroughly, the mix should be immediately transported to the laying site in suitable vehicles. Too much mixing should be avoided as it may result in de-coating of aggregates.

When mixed manually by shovels, 0.06 cum of aggregates can be conveniently mixed in one heap, with appropriate quantity of emulsion. It is preferable to make the aggregates damp before mixing as it reduces the effort required for mixing and also assist with better coating of aggregates. The 13.2 mm size aggregates and emulsion are mixed first and then the 11.2 mm size aggregates and remaining quantity of emulsion are added and mixed. Too much mixing should be avoided as it will result in decoating of aggregates.

8.4.9.6. Spreading and rolling : The premixed cationic bitumen emulsion and aggregates should be spread within 10 minutes of applying the tack coat. The mix is easily workable for about 20 minutes after mixing and hence all levelling, raking, etc. should be completed within this time for easy workability, and subsequent compaction.

The mix should be spread uniformly to the desired thickness, grades' and crossfall (camber) making allowance for any extra quantity required to fill up depressions, if any. The crossfall should be checked means of camber boards and any irregularities attended to. Excessive use rakes should be avoided.

The rolling should start immediately after laying the premix. A smooth wheeled tandem roller of 8 0 tonnes can be used but a three wheeled steel roller of equivalent capacity is preferred. While rolling, wheels of the roller should be clean and a suitable application to prevent the premix from adhering to wheels should be used as previously mentioned.

Rolling should commence at the edges and progress towards the centre longitudinally except in the of superelevated and uni-directional cambered sections where rolling should progress from the lower e towards the higher edge parallel to the centre line of the road.

After one pass of roller over the whole area, depressions or uncovered spots should be corrected by adding premix material. Rolling should be continued until the entire surface has been properly compacted and all the roller marks eliminated. In each pass of the roller the preceding track should be overlapped uniformly by at least 1/3 width. Roller(s) should not stand on newly laid material while there is a risk that it will be deformed thereby. Joints along and transverse to the carpet laid and compacted earlier should be cut to their full depth so as to expose fresh surface which should be painted with a thin surface coat of binder before the new mix is placed against it.

8.4.9.7. Seal coat : A seal coat, should be applied 4 to 6 hours after laying the premix carpet.

8.4.9.8. Opening to traffic : Traffic should not be allowed over the premix surface with or without [coat, for 6 to 8 hours after rolling. In case of single-lane roads, traffic may be allowed earlier, but the speed of traffic must be strictly controlled. If any premix material is picked up by vehicle tyres, the spot should be filled by new mix. It is preferable not to open the road to traffic for at least 24 hours.

8.4.9.9. Surface finish and quality control : The surface finish of construction should requirements conform to given in Chapter 10.

8.4.10. Close-graded premix surfacing/mix seal surfacing (Clause 512 of Ministry's Specifications)

8.4.10.1. Construction operations : Requirements are as stated in paras 8.4.8.1 to 8.4.8.5.

8.4.10.2. Opening to traffic : Traffic may be allowed after completion of the final rolling when the mix has cooled down to the surrounding temperature.

8.4.10.3. Surface finish and quality control of work : The surface finish of construction should conform to the requirements given in Chapter 10.

8.4.11. Premix seal coat (Clause 512 of Ministry's Specifications)

8.4.11.1. Weather and seasonal limitations : Laying should be suspended while free-standing water is present on the surface to be covered. Laying should be avoided as far as is practicable during rain, fog and dust storms, and if these conditions threaten to be prolonged laying should be suspended. Laying of bituminous mixtures should not be carried out when the air temperature at the surface on which it is to be laid is below 10°C or when the wind speed at any temperature exceeds 40 km/hr at 2 m height unless specifically approved and then only provided that rolling can be completed before the mixture cools below the specified minimum compaction temperature for the mixture.

8.4.11.2. Preparation of base : The seal coat should be applied immediately after laying the bituminous course which is required to be sealed. Before application of seal coat materials, the surface should be cleaned free of any dust and other extraneous matter.

8.4.11.3. Construction of premix seal coat : A mixer of appropriate capacity and type should be used for preparation of the mix material. The plant should have separate dryer arrangements for heating aggregates.

The binder Should be heated in boilers of suitable design, to the temperature appropriate to the grade of bitumen. Also, the aggregates should be dry and heated to a suitable temperature before the same are placed in the mixer. Mixing of binder with aggregates to the specified proportions should be continued till the latter are thoroughly coated with the former.

The mix should be immediately transported from the mixing plant to the point of use and spread uniformly on the bituminous surface to be sealed.

As soon as a sufficient length has been covered with the premixed material, the surface should be rolled with an 8 to 10 tonne smooth-wheeled roller. Rolling should be continued until the premixed material is completely sealed and a smooth uniform surface without voids is obtained.

8.4.11.4. Opening to traffic : Traffic may be allowed soon after final rolling when the premix material has cooled down to the surrounding temperature.

8.4.11.5. Surface finish and quality control of works : The surface finish of construction should conform to the requirements given in Chapter 10.

8.4.11.6. Arrangements for traffic : During the period of construction, arrangements for traffic should be made in accordance with the provisions of para 8.2.3.

8.4.12. Mastic asphalt (Clause 515 of Ministry's Specifications)

8.4.12.1. Weather and seasonal limitations : Laying should be suspended while free-standing water is present on the surface to be covered. Laying should be avoided as far as is practicable during rain, fog and dust storms, and if these conditions threaten to be prolonged, laying should be suspended. Laying of bituminous mixtures should not be carried out when the air temperature at the surface on which it is to be laid is below 10°C or when the wind speed at any temperature exceeds 40 km/hr at 2 m height unless specifically approved, and then only provided that rolling can be completed before the mixture cools below the specified minimum compaction temperature for the mixture.

8.4.12.2. Preparation of the base : The base on which mastic asphalt is to be laid should be prepared, shaped and conditioned to the profile required. In the case of a cement concrete base, the surface should be thoroughly power brushed clean and free from dust and other deleterious matter. Under no circumstances should mastic asphalt be spread on a base containing a binder which might soften under high application temperatures used for mastic asphalt.

8.4.12.3. Tack coat : A tack coat in accordance with para 8.3.2 should be applied on the base.

8.4.12.4. Preparation of mastic asphalt : The presentation of mastic asphalt for immediate use and for casting into blocks for use at a later date are outlined below in sub-paras A and B.

(A) For Immediate Use : The preparation of mastic asphalt consists of two stages. The first stage consists of mixing of filler and fine aggregates and then heating the mixture to a temperature of 170°C to 210°C. Required quantity of bitumen is heated to 170°C to 180°C and added to the heated aggregate. They are mixed and cooked in an approved type of mechanically agitated mixer called mastic cooker till the materials are thoroughly mixed. Initially, the filler alone is to be heated in the cooker for an hour and then half the quantity of binder is added. After heating and mixing for some time, the fine aggregates and the balance of the binder are to be added and further cooked for about one hour. The second stage is incorporation of coarse aggregates and cooking the mixture for a total period of 3 hours. During cooking and mixing, care is to be taken to ensure that the contents in the cooker are at no time heated to a temperature exceeding 210°C.

(B) For Casting into Blocks : Where the material is not required for immediate use it should be cast into blocks consisting of filler, fine aggregates and binder, but without the addition of coarse aggregate, weighing about 25 kg each. The mastic asphalt blocks should show on analysis a composition within the limits as given in Table 8.4. Before use, these blocks should be reheated to a temperature of not less than 175°C and not more than 210°C, and the coarse aggregate should then be thoroughly incorporated in the mastic. Mixing should be continued until laying operations are completed so as to maintain the aggregates in suspension. At no stage during the process of mixing should the temperature exceed 210°C.

Table 8.4. Composition of Mastic Asphalt Blocks without Coarse Aggregates

IS Sieve	Percentage by weight of mastic asphalt	
	Minimum	Maximum
Passing 2.36 mm but retained on 0.600 mm	0	22
Passing 0.600 mm but retained on 0.212 mm	4	30
Passing 0.212 mm but retained on 0.075 mm	8	18
Passing 0.075 mm	25	45
Bitumen Content	14	17

The mixture should be transported to the laying site in suitable mixer/transporter having an arrangement for stirring and keeping the mixture hot during transportation.

8.4.12.5. Spreading : The mastic asphalt should be laid, normally in one coat, at a temperature between 175°C and 210°C and spread uniformly by hand using wooden floats or by machine on the prepared and regulated surface. The thickness of the mastic asphalt and the percentage of added coarse aggregate should be in accordance with Table 4.18. Where necessary, battens of the requisite dimensions should be employed. Any blow holes or blisters that appear in the surface should be punctured while the material is hot, and the surface made good by further floating.

8.4.12.6. Joints : All construction joints should be properly and truly made. These joints should be made by warming existing mastic asphalt by the application of an excess quantity of the hot mastic asphalt mixture which afterwards should be trimmed to leave it flush with the surfaces on either side.

8.4.12.7. Surface finish : The mastic asphalt surface can have poor skid resistance after floating; in order to provide resistance to skidding, the mastic asphalt after spreading, while still hot and in a plastic condition should be covered with a layer of stone aggregate. This aggregate should be 13.2 mm size (passing the 19.0 mm sieve and retained on the 9.5 mm sieve) or 9.5 mm size (passing the 13.2 mm sieve and retained on the 6.7 mm sieve) subject to approval by the Engineer-in-Charge. Hard stone chips, complying with the quality requirements of Table 4.9 and para 4.3.2.3 should be precoated with bitumen at the rate of 2 ± 0.4 per cent of S-65 penetration grade. The addition of 2 per cent of filler complying with the requirements of para 4.3.2.3 (c) may be required to enable this quantity of binder to be held without draining. The chips should then be applied at the rate of 0.005 cu m per 10 sqm and rolled or otherwise pressed into the surface of the mastic layer when the temperature of the mastic asphalt is not less than 100°C

8.4.12.8 Opening to traffic: Traffic may be allowed after completion of the work when the mastic asphalt temperature of the completed mastic asphalt layer has cooled to the daytime maximum ambient temperature.

8.4.12.9. Surface finish and quality control of work : the surface finish of the completed construction should conform to the requirements given in Chapter 10.

The surface of the mastic asphalt, tested with a straight edge 3.0 m long, placed to the centre line of the carriageway, should have no depression greater than 7 mm.

8.4.13. Slurry seal (Clause 516 of Ministry's Specifications)

8.4.13.1. Weather and seasonal limitation: Laying should be suspended while free-standing water is present on the surface to be covered. Laying should be avoided as far as is practicable during rain, fog and dust storms, and if these conditions threaten to be prolonged laying should be suspended. Laying of bituminous mixtures should not be carried out when the air temperature at the surface on which it is to be laid is below 10°C or when the wind speed at any temperature exceeds 40km/hr at 2 m height unless specifically approved, and then only provided that rolling can be completed before the mixture cools below the specified minimum compaction temperature for the mixture.

8.4.13.2. Surface preparation : Any necessary remedial work to the road surface and structure should be completed before application of the seal.

Before the slurry seal is applied, street furniture and, road markings, kerbs etc., should be masked using self-adhesive masking material or other material firmly secured against the passage of the passage of spreader box or the tools used for hand laying. Any packed mud or other deposits on the surface should be removed; all organic growth should be removed by suitable means, and the surface should be swept free of all loose material.

8.4.13.3. Tack coat: If required, a tack coat may be applied prior to the slurry seal, with or without grit or chips, in order to seal the existing surface and enhance the bond to the existing road road surface. The rate of spread of tack coat should be 0.20 to 0.25 kg/m^2 for bituminous surfaces and 0.30 to 0.35 kg/m^2 for concrete surfaces.

8.4.13.4. Mixing and transportation of mixture: Mixing (and laying) techniques vary according to the type of emulsion used. For class A4 rapid setting and K3 emulsions, only special mobile mixing machines should be used. These carry supplies of aggregates, emulsion, water and filler (e.g. ordinary Portland Cement or hydrated lime) and are fitted with metering devices to feed the ingredients in their correct proportions to a mixer fitted to the rear of the machine. From the mixer the slurry is fed into the screed box towed by the machine.

For all other emulsions, mixing may be by hand, concrete mixer or other mixer or other mixer which effectively coats the aggregate uniformly and produces a slurry seal of suitable consistency for satisfactory laying. For large areas, a bulk transit concrete mixer may be used into which the ingredients (including water) are measured and mixed as the mixer travels to the area to be treated. A screed box fitted with and adjustable rubber screed should be towed by the mixer which feeds it during laying.

The special mobile mixing machine, when used, should be capable of uniform application to provide a continuous surface without ridges or segregation.

where the material is to be hand laid the slurry may be supplied to site pre-mixed in suitable containers and steps should be taken to ensure that the material in each container is of and even consistency throughout the container immediately prior to use.

8.4.13.5. Application: Transverse joints for machine laid areas should be formed with spreading starting and finishing on a protective strip no less than 100 mm wide at each end of the lane length being treated. Transverse joints should be formed such that there should be no ridges or bare strips.

The longitudinal joints should coincide with lane markings Longitudinal joints should be formed such that there should be no ridges or bare strips.

Handwork around street furniture and other ironwork should meet the same performance requirements and form a homogenous surface with the rest of the treated carriageway.

Footways and other confined areas may be spread by hand using squeegees and brooms Transverse joints should be formed with spreading starting starting and finishing on a protective strip not less than 100 mm wide at each end of the lane length being treated. Transverse joints should be formed such that there should be no ridges or bare strips. Kerb edges and other areas not being treated should be suitably masked with self-adhesive masking material Footways should be finished by dragging a dampened broom transversely over the footway under its own weight.

All voids, cracks and surface irregularities should be completely filled. In warm dry weather the Surface, immediately ahead of the spreading, should be slightly damped by mist water spray applied mechanically, or for hand laying by a hand operated pressure sprayer.

8.4.13.6. Rolling: Where rolling is required, a pneumatic-tyred roller having and individual wheel load between 0.75 and 1.5 tonnes should be used Rolling should commence as soon as the slurry has set sufficiently to ensure that rutting or excessive movement will not occur.

8.4.13.7. Opening to traffic : Masking should be remove after the slurry seal has been applied, without damage to the edge of the surfacing, and before opening the road or footway to traffic.

After closely monitoring for a minimum period of 2 hours, if necessary the lane should be swept again. The monitoring should continue until the slurry seal has reached sufficient stability to carry unrestricted traffic. If there are signs of distress, traffic safety and management procedures or other such remedial action necessary to prevent further damage should be adopted.

Further operations to remove subsequently loosened aggregate should be carried out over the next 48 hours. The areas treated and adjacent side roads, footways and paved areas should be kept substantially free of loose aggregate for a period of 30 days after completion of the work.

8.4.13.8. Surface finish and quality control of work: Generally, the surface finish of the completed construction should conform to the requirements given in Chapter 10.

In addition, the finished slurry should have a uniform surface texture throughout the work, without variations of texture within the lane width, or from lane to lane, due to segregation of aggregates, or due to variations in the emulsion/water content of the mixture.

The finished surface should be frec from blow holes and surface irregularities in excess of 3 mm beneath straight a I m straight edge due to scraping, dragging, dropping, excess overlapping or badly aligned longitudinal or transverse joints, damage by rain or frost, or other defect which remain 24 hours after laying.

8.4.13.9. Arrangements for traffic: During the period of construction, arrangements for traffic should be made in accordance with para 8.2.3.

8.4.14. Recycling of bituminous Pavement (Clause 517 of Ministry's Specification) : Recycling of bituminous pavement involves the pavement removal, stockpiling of materials from the old pavement, addition of new bitumen and untreated aggregate in the requisite proportion, mixing, spreading and compaction of the blended materials The recycling process can be categorised into central plant recycling (where rcclamcd matcrial is processed off site) and in situ recycling (where processing takes place on site). These processes can be further subdivided into hot and cold processes. The hot mix recycling has been described bclow in para while the cold mix recycling has been dealt with in para 8.4.14.2.

8.4.1.4.1. Hot mix recycling

(A) Central plant Hot Mix Recycling

(a) Reclamation of the bituminous pavement

This is generally done either by milling or by ripping and crushing, described below and the reclaimed material stockpiled where necessary.

(i) **Milling:** Reclamation by milling, with special machines, is commonly employed for thin layer reclamation or partial depth rcclamation work and is very suitable for urban areas, particularly as its use may permit as its use may permit continued trafficking of the road in areas where closures would cause congestion.

In thin layer reclamation and recycling work it is sometimes convenient to use continous single-pass in-place recycling equipment although milled material may also be transported to a central plant, stockpiled and used for hot or cold mixing. Milling, when properly done, helps to correct and improve the surface profile.

Advantages of milling are :

- high productivity,
- no further need of need of crushing involved,
- very little dust, toxic fumes or heat generation,
- achieving better texture and profile of the existing surface, and
- milling work can be carried out on a single lane while other adjacent lanes remain open to traffic.

Milling can, however, lead to degradation of aggregates and production of excessive fines; this must be taken into consideration in any mix design using the milled material.

(ii) **Ripping and Crushing:** Ripping and crushing are required generally when full-depth removal of bituminous pavement is involved This will normally result in traffic closures for substantial duration. conventional equipment include rippers (Fig.8.26) fitted to bull- end loaders, and motor graders, use for ripping and breaking operations; the consequent avoidance of the need to procure specialist milling equipment is often seen as an advantage.

The product of the ripping operation is then transported to a convenient processing site where it is crushed and pulverised with grid-rollers, hammer mills or specialised pulverising equipment Standard jaw crushers with two sets of rollers have also been successfully used The first full forms flat pieces (like pancakes) out of the big chunks and the second roll breaks the pancakes into small fragments.Foe optimum performance the attempts should be made to crush the reclaimed material to 40 mm size (although, in practice, it is often necessary to accept and upper limit of 50 mm) Every effort must be made during the crushing operation to avoid loss of material, particularly fines.

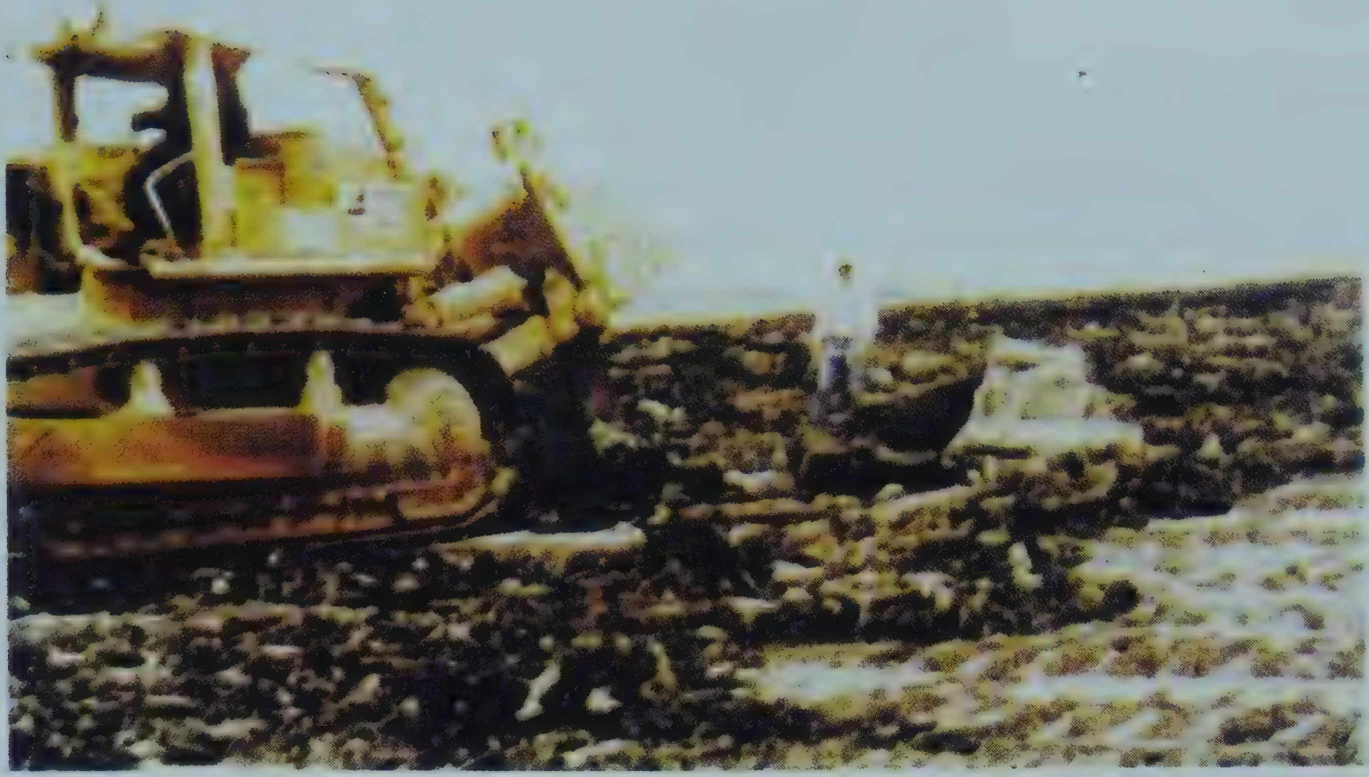


Fig. 8.26. Ripping of Asphalt Layer being carried out with a Bullozer

(iii) **Stockpiling:** Because of the probable time-lag between different construction operations, and also because it may not be possible to use the entire reclaimed material in one job, the reclaimed bituminous material will usually be stored in stockpile. Owing to the presence of bitumen, with time and under pressure of the load, the stockpiled material tends to congeal into chunks. Segregation can also be a problem.

Some general precautions should be noted:

- Use only front end loaders for stockpiling (bull-dozers tend to compact the stockpiled material)
- Limit the height of the stockpiles, preferably to 2 metres, but never more than 3 metres.
- Provide good drainage to the stockpile area and try to avoid, excessive wetting-up of the stockpile.

Reclaimed material from different sources should be stockpiled separately, and the separate sources clearly recorded.

(b) Mixing in Central Hot Mix Plant

Reclaimed Material is often re-cycled with the addition of virgin material, in either a batch type or drum type mixing plant, with minor modifications. The commonly used method of heating the reclaimed material is by the 'heat transfer' method in which the super-heated virgin aggregates are mixed with the cold reclaimed material and transfer their extra heat to the reclaimed material

In the batch type plants, mixing of the virgin aggregate id performed in the standard hot-mix plant channel through feeders, dryers, elevator etc. to the pug mill mixer. The reclaimed material is fed directly to the pug mill weighing box by a separate channel consisting of its own feeding bin, converyor belt and chute.

It is possible, in this way, to process material in which the ratio of reclaimed material to new material is in the range of 35:65 per cent to 50:50 per cent. The proportion of reclaimed material that can be processed depends upon:

i. the percentage moisture fin the reclaimed

ii. the required final discharge temperature,

iii. the temperature of the material at stockpile,

iv. the temperature to which the virgin aggregate can be heated, and

v. the exhaust capability of the pugmill or the weigh-hopper for steam generated from the moisture content in the reclaimed material.

For obvious reasons, higher the production rate required, lesser will be the exit temperature of the mixture. As the superheated virgin aggregates come into contact with the moist reclaimed material, a large quantity of steam is generated which must escape. Some steam escapes through the reclaimed material entry chute but for a large quantity production a separate exhaust kluct needs to be provided in the pug-mill or the weigh-box. This avoids a number of significant problems.

The following guidelines are for assistance in achieving better performance:

(i) Bitumen is a bad conductor of heat and heat transfer from fresh aggregates to the bitumen-coated reclaimed material is a somewhat time-consuming process and continues even after discharge from the pugmill. Generally, in order to make it complete, the mix material is kept for an intermediate duration in an insulated hot mix storage silo (surge hopper) before being delivered to the truck. The waiting period in the storage silo completes the heat transfer.

(ii) The cold feed bin for reclaimed material should not be very big or deep and should have a broad opening at the bottom to prevent congealing.

(iii) The feeder bin should not be subjected to any type of vibration to prevent compaction of the feed.

(iv) The reclaimed material should not be the first material in the sequence of loading into the weigh-box in order to prevent compaction due to the weight of material over it.

(v) For high production rates the wet scrubbing system of dust extraction cyclone should be provided instead of a simple cyclone.

Drum mix plants can also be used for mixing recycled material. Several improvements have been in troduced to eliminate blue smoke emission and also relieve material build-up (see Chapter 6). Many of the devices are proprietary and vary depending on the manufacturer.

As in, the batch-type plant, the production rate in drum mixer is influenced by a number of factors:

- the initial temperature of the fresh aggregate cold feed and the reclaimed material,
- the temperature required in the final mix as per design and
- the moisture content of the reclaimed material and the fresh cold feed.

Comparing plant for plant, the drum mixer is able to use a higher ratio of reclaimed material and also, generally has a higher production rate. A commonly used ratio of reclaimed material to fresh material is 60:40 per cent, to 70:30 per cent.

The advantages of a drum mixer recycling plant are: -

- higher production rate,
- higher achievable ratio of reclaimed material to fresh material,
- achieving better mixing by drum length adjustment and
- the plant is more compact and portable.

(c) Spreading and Rolling

In general, the work of laying and compacting recycled bituminous material is similar to that for other hot bituminous mixtures. However, a general observation has been that recycled mixes are relatively stiffer than fresh hot bituminous paving material. They may, therefore, require application of more compactive effort to achieve the required compaction.

Because of the general complexity of the nature of the work and chances of variation in the constituents of the recycled mixtures, the need for stringent quality control is even more crucial for recycling work than it is for new construction. Because it is difficult to maintain the strict aggregate grading requirements of the Marshall mix design method, recycled material is better suited for use,in a more open textured macadam.

B. In-situ Hot Recycling

In in-situ hot recycling, the entire series of operations are carried out at site which consist of either milling or ripping, breaking, pulverising and then mixing materials with binder and rejuvenating agent.

Reclamation : Conventionally, reclamation of existing bituminous material for use in in-situ recycling, can involve the use of milling, provided that the thickness to be recycled is not more than 25 mm. For thicknesses greater than 25 mm bull-dozers with rippers, front end loaders or motor graders with hardened cutting edges are used for the reclamation operation. Special pulverising equipment, like grid rollers or hammer-mills are then used to reduce the recycled material to the required size and grading.

Milling : Cold milling machine has a cutting drum with a series of tungsten carbide tipped cutting tools. These tools are arranged in a double-helix flight design to cut upward into the pavement material, bottom to top, as the machine moves forward.

The product of cold milling is very fine material, often 5 mm down, whereas hot milling will reclaim the stone with a grading much as it was laid.

Hot Planing : In this process the road surface is heated before scarifying. Heating is usually by means of infrared heaters or plates heated by gas. The equipment should maintain a continuous slow progressive movement, as static heating may overheat the binder.

Planing must follow closely behind the heaters and a milling drum with tungsten carbide cutting discs should closely follow the heaters.

The depth, and width of the material to be recovered, and speed of travel of the equipment can be controlled to suit design requirements.

Common Processes of Insitu Hot Recycling : Hot in-situ recycling processes may be sub-divided into three categories, according to the intended purpose of the operation:

- re-shaping,
- re-paving, and
- re-mixing.

The above categories are outlined below :

Re-shaping : This is generally carried out for purposes of minor re-profiling as well as rejuvenation of the asphalt surface and may involve operations up to a depth of not more than 20 mm. The equipment hot-planes the surface, scarifies it and then mixes it with a recycling agent and new binder. The mixture is then placed to the required profile and rolled. This process thus improves the riding quality, reseals the road against water penetration, and improves skid resistance.

The original thickness of the pavement is, however, not changed in any significant way during re-shaping process and is of no use in cases of base failure.

If for any reason, the reclaimed material is not to be used, it should be stockpiled for subsequent use in foot-paths, park roads or similar situations where less stringent specifications are applicable, and a fresh bituminous mixture prepared for use in resurfacing.

Re-paving : The life of a road with a sound base structure may sometimes be extended by this process. The existing pavement surface is pre-heated (by infra-red or similar devices) and scarified (for better bond with the existing pavement) but the scarified material is not removed. A layer of fresh bituminous mix material prepared in the integrated mixing unit of the plant is then spread evenly on the scarified surface to give a uniform profile. The spread material should be compacted as soon as possible after laying. In this process the total thickness of the pavement is increased by up to 50 mm.

There are single-pass machines, with a front-hopper to receive fresh hot bituminous mix from a central hot-mix plant, a set of infrared heaters to heat and soften the pavement, which is then loosened by a scarifier following the heater. New hot mix material is carried by a heated conveyor belt and spread evenly to the required profile by a screed over the heated and levelled scarified layer. The spread material is tamped by a vibrator and finally compacted by a roller to complete the re-paving process.

Re-mixing : During this process, the scarified material should be taken from the road surface and transferred to the mixing unit of the plant where it is recycled with fresh binder, aggregate and rejuvenating agent. Then the recycled mixture is spread on the pre-heated surface and compacted to the required profile.

In the single-pass machines, as mentioned above for 'Repaving' purposes, if 'Remixing' is to be done, the scarified material, instead of being heated and levelled, is transported to the middle of the machine where a pugmill mixes the old and the new materials. From the pugmill, the recycled mix is fed into the screed where the screws evenly spread it in front of the screed which then levels it to the required profile. Rolling provides the final compaction.

The process of remixing also involves some increase in the overall thickness of the pavement.

8.4.14.2. Cold mix recycling

A. Central Plant Cold Mix Operation

The procedure for cold mix operation in a central plant, with regard to reclamation, haulage, stockpiling, etc., is the same as for hot mix operation. The material can be pulverised at site or at the plant. However some differences that should be noted, are as follows :

Since no heating is required, the recycling may be carried out without addition of new aggregates i.e., the same material will be given a new life with fresh binder and rejuvenating agent, (if required), provided that the reclaimed material exhibits acceptable grading characteristics. It is a usual requirement that the recycled layer is covered by a further hol bituminous surface layer.

For roads having medium to heavy traffic, the cold recycled layers can serve as improved and structurally strong base.

In practice, the cold central plant is considered to achieve higher mixing efficiency and higher production rates that in-situ cold mixing (described in para B below) and is, therefore preferred.

B. Insitu Cold Mix Recycling

Conventionally, the insitu method of cold recycling involves either milling of the existing surface, usually when less than 25 mm, or ripping, breaking, pulverising the same (when thickness is large) by bull dozer with ripper, front-end loader or motor graders. However, modern recycling machines can mill upto 300 mm depth and recycle upto 250 mm depth, thus avoiding the use of bull dozer upto 250 mm depth. When the broken size is large, it is reduced by the methods similar to that for hot in-situ recycling. Cold emulsified binder and rejuvenating agent are then sprayed on the layer. If fresh material is to be added a cold mix of emulsion and aggregates, in design quantities, is then spread on it. The two materials are then mixed, spread to the required thickness and profile, and compacted by rollers.

The process of milling for cold in-situ recycling is the same as described under the hot process. The actual recycling work may, however, take various forms.

A very simple and economical way of in-situ recycling is to break the existing course in-place and then to spread the new aggregate, in quantities in accordance with the design requirements, on to the scarified surface and to pulverise the loose aggregate composition (during which process the newly spread aggregates are incorporated). Emulsified bitumen should be sprayed onto the surface and the material mixed in-situ and compacted by roller, preferably to refusal.

Clearly, the method described above is imprecise and should only be used on lightly trafficked roads and on roads where the bitumen in the wearing course has become oxidised and brittle.

Before opening the surface of the road to traffic, a single or double-seal surface dressing should be provided. The process is sometimes called 're-treating' and is considered to be a cost-effective maintenance measure in appropriate lightly trafficked situations.

For medium, trafficked roads, deeper in-situ pulverisation followed by in-situ addition of emulsion may be used However, these restored courses are seldom used as the final wearing surface and are usually over-laid by a new bituminous wearing course or a new strengthening course.

The highly trafficked roads, the insitu cold mix recycling is not considered suitable and central plant cold mix recycling must be resorted to which gives high production rates and close control of mix design.

8.4.15. Stone Mastic Asphalt (SMA) (New Specification)

8.4.15.1. Weather and seasonal limitations : Laying should be suspended while free-standing water is present on the surface to be covered. Laying should be avoided as far as is practicable during rain, fog and dust storms, and if these conditions threaten to be prolonged laying should be suspended. Laying of bituminous mixtures should not be carried out when the air temperature at the surface on which it is to be laid is below 10°C or when the wind speed at any temperature exceeds 40 km/hr at 2 m height unless specifically approved, and then only provided that rolling can be completed before the mixture cools below the specified minimum compaction temperature for the mixtures.

8.4.15.2. Preparation of base : Existing surfaces should be prepared in accordance with para 8.4.7.2. SMA should always be laid over a bituminous base and a prime coat is not therefore required.

8.4.15.3. Tack voat : A tack coat over the base should be applied in accordance with para 8.3.2. The preferred tack coat should be K 1-40 cationic bitumen emulsion. It should be spray-applied at a rate of 0.3-0.5 litres/m^2 to completely break before the stone mastic asphalt is laid.

8.4.15.4. Preparation and transportation of the mix : Paras 8.4.2 and 8.4.3 are also applicable here. A batch plant must be used. The temperature of SMA on discharge from the mixer pugmill must be in the range 150°C to 170°C for S-55 or S-65 bitumen, to facilitate subsequent compaction. There are several ways to proportion the fibres;

- Feeding in loose fibre from plastic bags by hand;
- Air blowing loose fibres directly in to the mixer pugmill;
- Proportioning of pellets (approximately 50 per cent fibres and 50 per cent low-melting binder) with a screw conveyor;
- Pre-mixing of bitumen and pellets in an agitated vat.

A mechanised method of addition should be used; exact proportioning of fibres and their homogenous distribution in the mixture before the bitumen is added is very important. To enhance the quality of SMA, mixing time should be extended by 10 to 15 seconds compared with that used for dense graded bituminous mixtures, and should be at least 50 seconds.

8.4.15.5. Spreading : Generally, para 8.4.4 is also applicable to this operation. The temperature of the mixture in the hopper of the paver should not be below 150°C. Compaction temperature should be as high as possible, consistent with a minimum rolling temperature of 100°C.

8.4.15.6. Rolling : Para 8.4.5 is applicable here. The temperature of the mixture in the hopper of the paver should not be below 150°C. Compaction temperature should be as high as possible, consistent with a minimum rolling temperature of 100°C.

A tandem drum roller should operate directly behind the paver, while another (steel wheeled) roller should be used for completion of rolling and the removal of all roller marks. Any use of vibration should be kept to a minimum (one or two passes) to preclude aggregate fracture and/or flushing of bitumen to the surface. Pneumatic tyred rollers should not be used.

Rolling should be continued until the density achieved is a minimum of 93 per cent and a mean value 95 per cent of Percentage Refusal Density (PRD). The required frequency of testing is defined in Chapter 10.

8.4.15.7. Opening to traffic : Stone mastic asphalt should not be opened to traffic until the aspha temperature, measured at the mid-depth of the layer, drops to 40°C. To improve early life skid resistance, an application of dust free grit may be applied after the first roller pass, at the following application rates:

- 1 - 2 kg/m^2 of 4.75 mm - 2.36 mm crushed coarse aggregate, or
- 0.6 - 0.9 kg/m^2 of 2.36 mm - 0.6 mm crushed fine aggregate.

All loose material must be removed at the completion of compaction.

8.4.15.8. Surface finish and quality control of work : The surface finish of the completed construction should conform to the requirements given in Chapter 10.

8.4.15.9. Arrangements for traffic : During the period of construction, arrangements for traffic should be made in accordance with para 8.2.3.

8.4.16. Bituminous cold mix (Clause 519 of Ministry's Specifications)

8.4.16.1. Weather and seasonal limitations : Construction with cold mix must not be undertaken when ambient temperatures below 10°C are expected or generally when poor weather is predicted. Bitumen emulsion and cutbacks depend on the evaporation of water and/or solvent for the development of their curing and adhesion characteristics. Cold weather, rain and high humidity slow down the rate of the curing. Extra manipulation may be required to remove the volatiles in cool and humid conditions. Wind increases the rate or evaporation.

8.4.16.2. Preparation of the base : The base on which cold mix is to be laid should be prepared shaped and conditioned to the required profile, and a prime coat where needed should be applied in accordance with para 8.3.1.

8.4.16.3. Tack coat : A tack coat in accordance with para 8.3.2 should be applied over the base on which the cold mix is to be laid if this base has a bituminous surface.

8.4.16.4. Preparation and transportation of the mixture : Mixing can be carried out using one the following types of mixer, which is provided with equipment for spraying the binder at a controll dosage or rate and, if necessary, for heating the binder to a temperature at which it can he applied uniformly to the aggregate.

(a) Rotary drum type concrete mixer;

(b) Single or twin shaft concrete or macadam mixer;

(c) Batch or continuous type mixer without dryer or screens other than a scalping screen.

A sufficient number of haul trucks with smooth, clean beds should be available to ensure continuous operation of the mixing plant and the paver, if used. The type of truck used for transporting the mixture from the mixer to the road site must be suited to the chosen laying procedure.

8.4.16.5. Spreading : Designed cold mix should be placed only when the specified density can be obtained. The mixture should not be placed on any wet surface or when weather conditions will otherwise prevent its proper handling or finishing or adhesion.

If spreading by motor grader, the grader must have a blade that is straight and sharp and long enough to ensure finishing to a close, straight, transverse tolerance and all joints and linkages must be in good condition. The grader must be heavy enough to hold the blade firmly and uniformly on the surface while spreading the mixture.

If climate conditions and aggregate grading permit evaporation of moisture or volatiles without aeration by manipulation, a conventional self-propelled asphalt paver may be used to place the cold mix.

Other approved types of spreader may also be used.

8.4.16.6. Compaction : Initial compaction of the laid material should preferably be carried out using a pneumatic-tyred roller of a weight appropriate to the layer thickness to be compacted. Smooth tyres should be used. Final rolling and smoothening of the surface should be done using steel wheel rollers which may be three-wheel type or a vibrating drum roller.

8.4.16.7. Opening to traffic : Traffic should not be allowed to run on new work until water or volatiles in the mixture have evaporated. The rate of evaporation will be influenced by the temperatures, humidity and wind conditions.

8.4.16.8. Surface finish and quality control of work : The surface finish of the completed construction should conform to the requirements given in Chapter 10.

8.4.17. Sand asphalt basecourse (Clause 520 of Ministry's Specifications)

8.4.17.1. Weather and seasonal limitations : Requirements of para 8.4.9.1 are applicable here.

8.4.17.2. Preparation of base : The surface on which Sand Asphalt basecourse material is to be laid should be prepared, shaped and conditioned to the profile required for the particular layer. The surface should be thoroughly swept clean free from dust and foreign matter using a mechanical broom, and the dust removed or blown off by compressed air. In locations where mechanical means cannot reach, other approved methods should be used. A priming coat, where needed, should be applied in accordance with para 8.3.1.

8.4.17.3. Tack coat : A tack coat over the base should be applied in accordance with para 8.3.2.

8.4.17.4. Preparation and transportation of the mixture : Paras 8.4.2 and 8.4.3 are also applicable to this material.

8.4.17.5. Spreading : Mixing must be accomplished at the lowest temperature and in the shortest time that will produce a mixture with complete coating of the aggregate and at a suitable temperature to ensure proper compaction. The ideal mixing and compaction temperatures for the particular bitumen in use should be obtained from the Bitumen Test Data Chart and should correspond to a viscosity of 2 Poise (0.2 Pas.) and 3 Poise (0.3 Pas.) respectively, based on the original (un-aged) bitumen properties. For guidance, ranges of acceptable mixing and rolling temperatures for typical penetration grade bitumens are shown in Table 8.3.

8.4.17.6. Rolling : Para 8.4.5 applies here. Generally the initial or breakdown rolling should be carried out with an 8 to 10 tonnes dead weight smooth-wheeled rollers. The intermediate rolling with 8 to 10 tonnes dead weight or vibratory rollers or with a pneumatic tyred roller of 12 to 15 tonnes weight having a tyre pressure of at least 0.7 MPa. The finish rolling should be done with 8 to 10 tonnes dead weight tandem rollers. The exact pattern of rolling should be established after compaction of a trial strip.

Rolling should be continued until the density achieved is a minimum of 93 per cent and a mean value of 95 per cent of Percentage Refusal Density (PRD). The required frequency of testing is defined in Chapter 10.

8.4.17.7. Opening to traffic : Traffic may be allowed after completion of the final rolling when the temperature of the mixture at the mid-depth of the competed layer has cooled to the daytime maximu ambient temperature. When daytime maximum ambient temperatures are in excess of 35°C, great care is needed to ensure this criterion is met, particularly where slow moving heavy traffic is involved.

8.4.17.8. Surface finish and quality control of work : The surface finish of the completed construction should conform to the requirements given in Chapter 10.

8.4.17.9. Arrangements for traffic : During the period of construction, arrangements for trafic should be made in accordance with para 8.2.3.

8.4.18. High performance base (New Specification)

8.4.18.1. Construction operations : Generally the requirements of para 8.4.7 (Dense-Graded Bituminous Material) should apply with respect to :

- Weather and seasonal limitations;
- Preparation of base;
- Tack coat;
- Preparation and transport of the mixture;
- Spreading;
- Rolling, including the Percentage Refusal Density (PRO) requirement as stated in para 8.4.7.6.

8.4.18.2. Protection of the layer : The high performance base should be covered with either the next pavement course or wearing course, as the case may be, within one or two days. If there is to be any delay extra care will be needed in surface preparation before the next pavement course is added. A seal coat should not be applied.

8.4.18.3. Surface finish and quality control of work : The surface finish of the completed construction should conform to the requirements given in Chapter 10.

8.4.18.4. Arrangements for traffic : As per para 8.4.17.9

8.4.19. Micro asphalt concrete (MAC) resurfacing (New Specification)

8.4.19.1. Weather and seasonal limitations : Laying should be suspended while free-standing water is present on the surface to be covered. Laying should be avoided as far as is practicable during rain, fog and dust storms, and if these conditions threaten to be prolonged laying should be suspended. Laying of bituminous mixtures should not be carried out when the air temperature at the surface on which it is to laid is below 10°C or when the wind speed at any temperature exceeds 40 km/hr at 2 m height unl specifically approved, and then only provided that rolling can be completed before the mixture cools below the specified minimum compaction temperature for the mixture.

8.4.19.2. Surface preparation : Any necessary remedial work to the road surface and structure should be completed before application of the MAC.

Before the MAC is applied, street furniture and, road markings, kerbs etc., should be masked using self-adhesive masking material or other material firmly secured against the passage of the spreader box. Any packed mud or other deposits on the surface should be removed; all organic growth should be removed by suitable means, and the surface should be swept free of all loose material.

8.4.19.3. Tack coat : If required, a tack coat may be applied prior to the MAC, with or without grit or chips, in order to seal the existing surface and enhance the bond to the existing road surface. The rate of spread of tack coat should be 0.20 to 0.25 kg/m^2 for bituminous surfaces and 0.30 to 0.35 kg/m^2 for concrete surfaces.

8.4.19.4. Mixing and laying : MAC is mixed on site and laid by a self-propelled machine equipped with hoppers, tanks and all necessary metering devices to ensure that the mix complies with the pre-determined mix formula. The equipment for laying is truck-mounted fitted with bin for aggregates, separate tanks for water and modified emulsion and a bin for cement. All the ingredients are mixed in a paddle mixer to a consistency for laying by paving unit attached to the equipment.

The spreader box is variable in width and has a double auger to distribute and homogenize the mix. It also has an application rate regulator to guarantee a uniform overlay. The applications, recommended gradations and standard application rates are as under :

Application	Aggregates	Application Rate (Kg/m^2)
Urban Roads and streets	0/6,0/10	8-11,10-14
Highways	0/12,0/10	12-16,10-14

If a double layer is applied, there should be a minimum period of 24 hours of traffic between the application of both layers. The minimum recommended amount can be applied in the first layer while a higher amount, but limited to the upper limit of the recommended amount can be applied in the second layer.

Although compaction is not normally needed, pneumatic compaction is recommended in jobs where traffic is not regular and is channelised or where traffic and weather conditions demand an extremely accelerated mix cohesion like on some heavily trafficked streets and at intersections.

8.4.19.5. Surface finish and quality control of work : Generally, the surface finish of the completed construction should conform to the requirements given in Chapter 10.

In addition, the finished MAC should have a uniform surface texture throughout the work, without variations of texture within the lane width, or from lane to lane, due to segregation of aggregates, or due to variations in the emulsion/water content of the mixture.

The finished surface should be free from blow holes and surface irregularities in excess of 3 mm beneath a 1 m straight edge.

8.4.19.6. Opening to traffic : Under favourable temperature conditions (greater than 25°C), the surface can be opened about 60 minutes after spreading. According to the work requirements, an emulsion can be formulated and setting controlled with an additive, such that opening to traffic can be performed as required. It is always advisable to delay opening to traffic to a maximum, so as to reduce the inevitable gravel loss to a minimum.

8.5. Construction with Polymer Modified Bitumen and Geosynthetic Material

8.5.1. Use of polymer modified bituminous construction : For the various items of road works involving the use of polymer modified bitumen, the specifications are essentially the same as those for penetration grade bitumen except those for any special conditions, which the manufacturer or supplier of additive may indicate. However, the following points are noteworthy in this context :

- All construction work using polymer modified bitumen should be carried out when the atmospheric temperature is above 15°C.
- Blending of modifier with bitumen should preferably be done at or near a hot mix plant site or supplied hot in tankers. If supplied in drums, agitation in melted condition with a suitable device is necessary for 10 to 15 minutes, before use.
- That the modifier is thoroughly blended with bitumen is of vital importance. While different types of modifiers require different techniques of blending, the essential requirements of storage stability must be satisfied, as reflected in the 'Separation Test' results (ASTM D 5976; outlined in Appendix 1 of IRC:SP:53).
- Tests for penetration (IS:1203), softening point (IS:1205), separation (ASTM D5976) and elastic recovery (ASTM D5976) should be conducted at the site for each lot of 5 tonne polymer modified bitumen.
- Mixing and rolling temperatures should be slightly higher than the conventional bituminous mixes, the exact temperature depending on the type and amount of modifier used and should be adopted as per the advice of suppliers

The range of temperatures at different stages are given in Table 8.5.

Table 8.5. Viscosity and Temperature Requirements for Use of Polymer Modified Bitumen in Bituminous Mixe

Stage of work	Viscosity	Temperature (°C)
Binder at mixing	Maximum 2 Poise	170-180
Mix at mixing plant	Maximum 4 Poise	145-165
Mix at laying site	Maximum 5 Poise	130-150
Rolling at laying, site	10-1000 Poise	115-135

Where preparatory products of polymer modified binder are used, test reports and full details for the use of these products at the site of work must be provided by the manufacturers.

8.5.2. Use of geosynthetics in bituminous construction

A. Material Requirements

Geosynthetic material can be used as bitumen overlay textile (paving fabric) beneath a pavement overlay or between pavement layers to provide a water resistant membrane and crack relief layer. The geosynthetic used in highway pavements should meet the physical requirements for paving fabrics as laid down in Table 8.6.

Table 8.6. Physical Requirements for Paving Fabrics

Property	Units	Standard Requirements	Test Method
Tensile Strength	Kg	36.3	ASTM D4632
Elongation	Per cent	50	ASTM D4632
Asphalt Retention	Kg/10 sqm	10	Texas DOT 3099
Melting Point	°C	150	ASTM D276
Surface Texture	--	Heat bonded on one side only	Visual Inspection

Notes : 1. Certification of conformance from fabric manufacturer may be required.

2. All numerical values represent minimum average roll values (average of test results from any sampled roll in a lot should meet or exceed the minimum values) in weaker principal direction. Lot should be sampled according to ASTM D4354, "Practice for Sampling of Geosynthetics for Testing".

3. Conformance of paving fabrics to specification property requirements should be determined as per ASTM D4759, "Practice for Determining the Specification Conformance of Geosynthetics".

The geosynthetic material should be kept dry and wrapped during storage and at no time should it be exposed to ultraviolet light for a period exceeding 14 days.

The tack coat used to impregnate the fabric and bond the fabric to the pavement should be an 80/100 having grade bitumen or an approved grade of emulsion; any cutbacks or emulsions which contain solvents should not be used.

B. Guidelines on Construction with geosynthetics

(i) Minimum air and pavement temperature should be at least 10°C and rising for placement of bitumen and should be at least 15°C and rising for placement of bituminous emulsion.

(ii) Prior to application of tack coat, the pavement surface should be cleaned of all dirt, water and oil etc. All cracks 3mm wide or greater should be cleaned and filled with suitable bituminous material. Prior to paving fabric placement, the crack filling material should be allowed to cure.

(iii) The tack coat should be applied uniformly to the prepared dry pavement at the rate of 1 kg/sqm in terms of residual bitumen or as recommended by the manufacturer of the fabric. Within intersections, on steep grades and other zones where vehicle speed changes are common, the application rate should be reduced by about 20 per cent. The tack coat application rate should be sufficient to saturate the fabric and to bond the fabric to the existing pavement surface. To avoid damage to the fabric, distributor tank temperatures should not exceed 160°C. For bitumen emulsion, the distributor tank temperatures should be maintained between 55°C and 70°C. The target width of tack coat application should be equal to the paving fabric width plus 150mm. The tack coat should be applied only as far in advance of paving fabric installation as is appropriate to ensure a tacky surface at the time of paving fabric placement. Traffic should not be allowed on the tack coat; any excess tack coat should be cleaned from the pavement.

(iv) The paving fabric should be placed onto the tack coat using mechanical or manual laydown equipment capable of providing a smooth installation with a minimum amount of wrinkling or folding. The paving fabric should be placed prior to the tack coat cooling and losing tackiness. Paving fabric should not be installed in areas where the overlay asphalt tapers to a tackiness of less than 40 mm. When bitumen emulsions are used, the emulsion should be allowed to cure properly so that no moisture remains prior to the placing of paving fabric. Wrinkles or folds in excess of 25 mm should be slit and laid flat. Brooming and/or pneumatic rolling may be required to maximise paving fabric contact with the pavement surface. Additional hand-placed tack coat may be required at laps to satisfy bitumen retention of the lapped paving fabric. All areas with paving fabrics placed should be paved the same day. No traffic except necessary construction equipment will be allowed to drive on the paving fabric.

(v) Turning of the paver and other vehicles should be done gradually and kept to a minimum, to avoid movement and damage to the paving fabric. Abrupt starts and stops should also be avoided. Damaged fabric should be removed and replaced by the same type of fabric. Overlap should be sufficient to ensure full closure of the joint but not exceed 150 mm.

(vi) Bituminous overlay construction should closely follow fabric placement. All areas in which paving fabric has been placed will be paved during the same day. Excess tack coat which bleeds through the paving fabric should be removed. Excess tack coat can be removed by broadcasting sand on the paving fabric.

8.6. Construction of Paved Shoulders

8.6.1. General : Basically roadside shoulder is a narrow lane designed to withstand limited traffic, adjacent to the traffic lanes which are designed to withstand much heavier traffic. The construction procedure is, therefore, essentially, the same as for paving the carriageway. Earlier, it was considered desirable to have the texture of surface material on the shoulder to be different from the main carriageway. Based on experience in the developed countries, it is now considered good practice to have the same surface material on the shoulder as the main carriageway and only provide a solid white painted line along the edge of the main pavement of carriageway for purposes of demarcating the shoulder.

8.6.2. Construction Procedure : If the paved shoulders are to be provided during the initial construction of the roadway itself, the same procedure should be adopted as for the main traffic lanes. If, however, paved shoulders are to be constructed adjacent to an already existing carriageway, essentially the same procedure should be adopted as for widening the existing carriageway. Trenches are first cut, to the required width and depth, by cutting templates or bits attached to a motor grader finished to the required line and grade. For compacting the subgrade of the trench to the required density a trench roller (Fig. 8.27) or vibratory roller should preferably be used. The vertical face of the pavement edge should be provided with a tack coat of bituminous emulsion. The base material is then placed in layers and compacted to the required density by vibratory roller, followed by the surface course.

While laying a surfacing bituminous mix, adjacent to the existing carriageway, the loose thickness of the mix should be enough to give the finished surface after compaction to the desired line and grade.

In the interest of least interference to moving traffic during the construction of shoulders to be added to an already existing carriageway, it is good practice to have a trench opened only to the extent that is needed for an efficient operation.

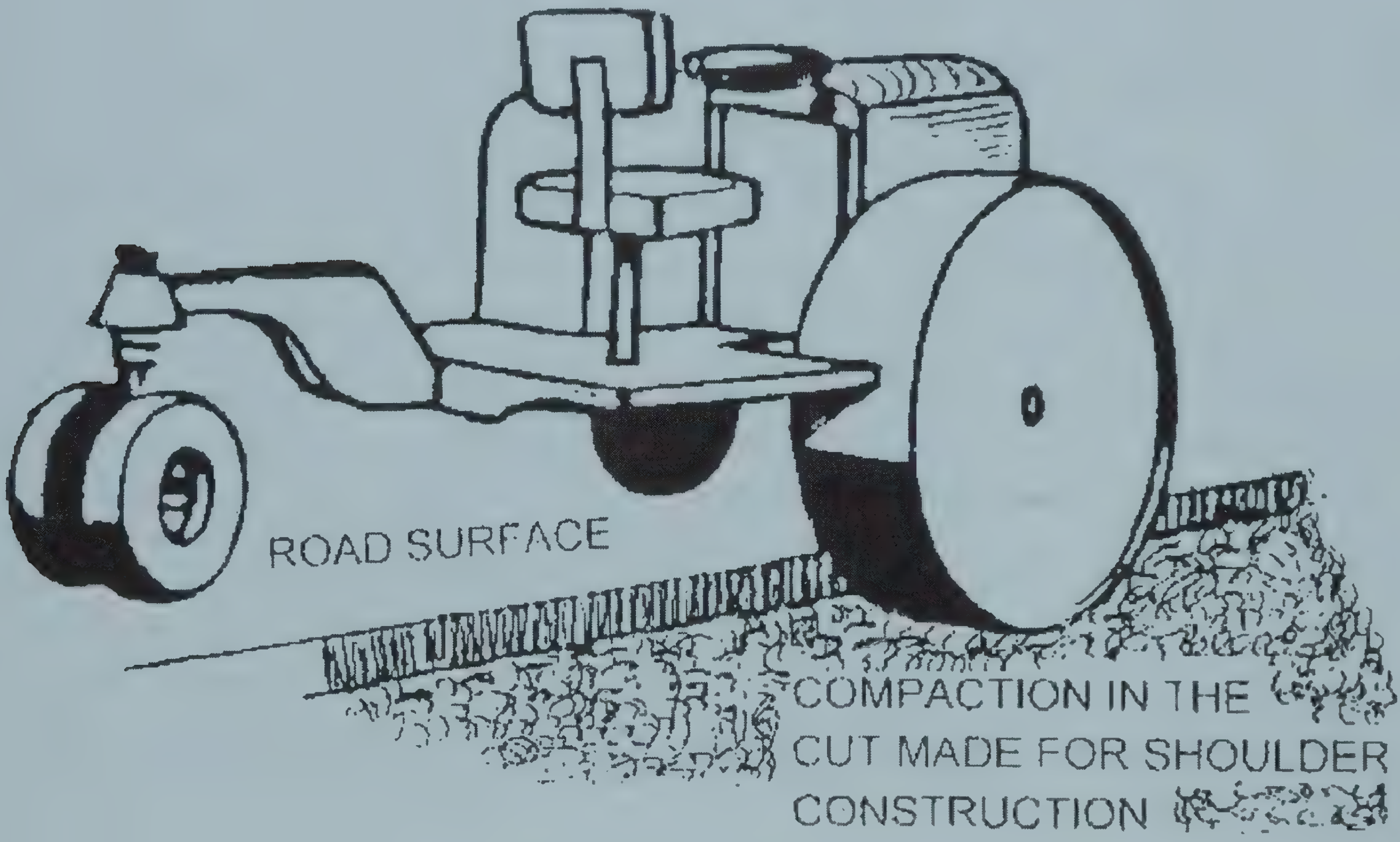


Fig. 8.27. A Trench Roller

8.7. Organisational Aspects

In order to ensure quality construction in road projects in general and those involving bituminous materials in particular, an essential pre-requisite is a well-organised set-up, be it a new construction project or rehabilitation or even a routine maintenance job. It is, however, to be recognised that no single organisational structure can be recommended for all road projects irrespective of the nature and size of the project which may range from a full depth asphaltic concrete pavement for an Expressway to a single coat surface dressing on a secondary road. Fig. 8.28 shows, in broad terms, an organisational set-up for a highway project; the number and level of various staff members under the Project Manager would, however, depend on the nature and size of the project. Bituminous materials being both expensive and highly complex in their engineering properties warrant careful controls right from the stage of laboratory testing and mix design to preparation of aggregate-bitumen mixture in a plant, laying by a paver-finisher,

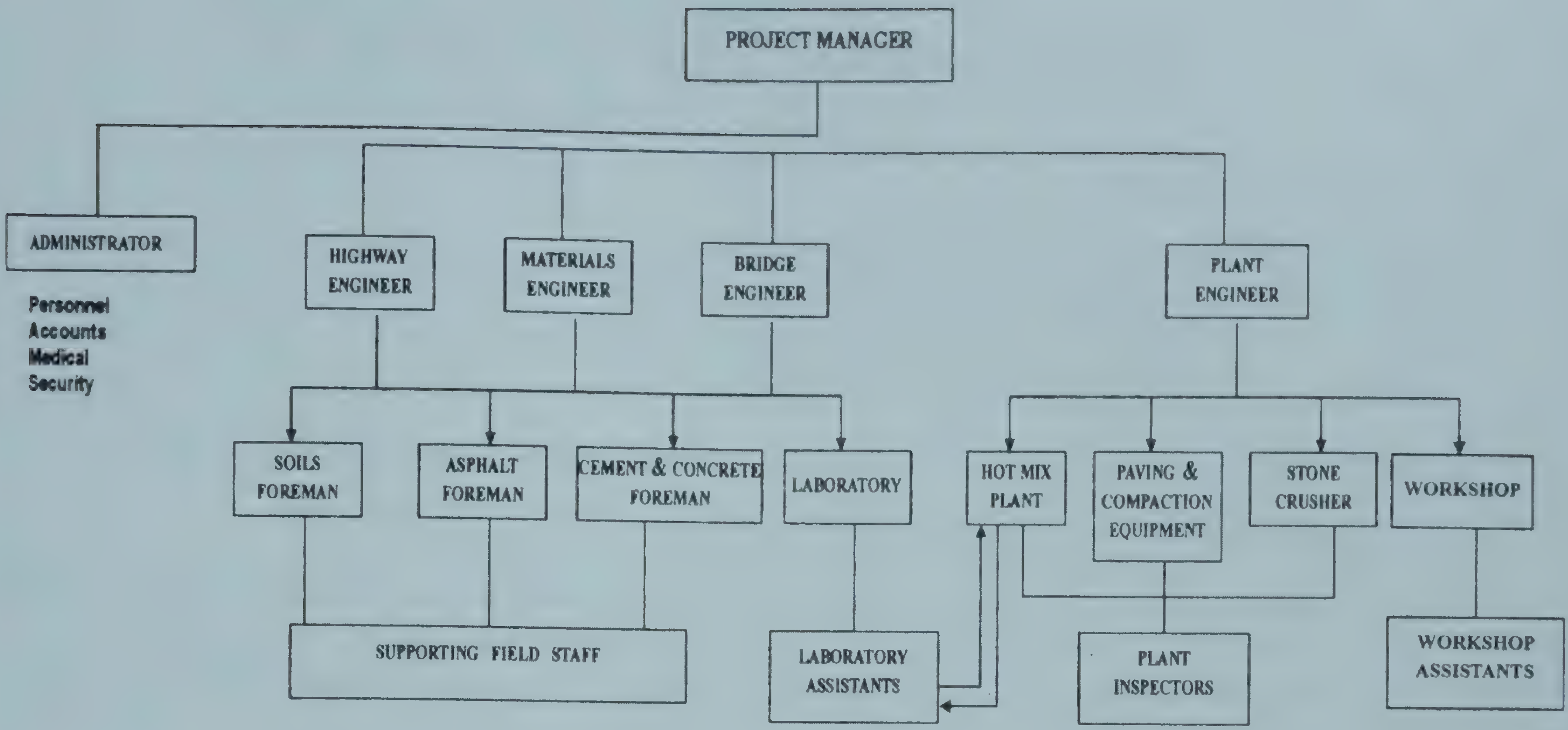

PROJECT MANAGER
ADMINISTRATOR
Personnel
Accounts
Medical
Security
HIGHWAY ENGINEER
MATERIALS ENGINEER
BRIDGE ENGINEER
PLANT ENGINEER
SOILS FOREMAN
ASPHALT FOREMAN
CEMENT & CONCRETE FOREMAN
LABORATORY
HOT MIX PLANT
PAVING & COMPACTION EQUIPMENT
STONE CRUSHER
WORKSHOP
SUPPORTING FIELD STAFF
LABORATORY ASSISTANTS
PLANT INSPECTORS
WORKSHOP ASSISTANTS

Fig. 8.28. Typical Organisational Set-up for a Highway Project

compacting and finishing within the tight specified tolerances. The properties of bitumen being highly temperature dependent, careful temperature controls, besides other controls, are of vital importance.

For any sizeable job on a National Highway Project; it is necessary to have the services of well-qualified Materials Engineers who have the requisite experience in evaluation of bituminous materials, designing of bituminous mixes, construction, rehabilitation and maintenance jobs. The asphalt foreman as shown in Fig. 8.28 should be well trained and experienced in the efficient operation of different types of asphalt plant and should be conversant with the laying of bituminous mixes with a paver finisher, compaction of the bituminous layer and quality control during construction. The staff of the testing laboratory ‘should be proficient in all the different types of tests on bituminous materials and mixes as are specified in the Ministry’s Specifications for Road and Bridge Works. Last but not the least is the important role of the efficient and safe operation of different types of plant and equipment used in bituminous works and attend to any adjustments and repairs that may be needed from time to time.

For bituminous works of lesser magnitude and of lesser importance in nature like providing a thin surface treatment of slurry seal or a routine maintenance job, an asphalt foreman should be in over-all change. Besides his technical inputs, he should also ensure that various safety requirements as set out in para 8.2.3 and shown in Fig. 8.5 and 8.6 are fulfilled.

CHAPTER 9

MAINTENANCE OF BITUMINOUS SURFACES

9.1. Need for Maintenance

A bituminous surface deteriorates with the passage of time owing to:

1. The action of traffic, especially of heavy commercial vehicles;
2. Environmental factors, such as ingress of water, oxidation of the binder and loss of volatiles;
3. Inadequacies in the initial design, specifications and construction standards of the bituminous layers; and
4. Lack of adequate support from the lower pavement layers.

Timely and proper maintenance will prolong the life of a pavement system. The pavement deteriorates at a relatively slow rate during the early years of its life, but as it approaches the end of its design life the rate of deterioration accelerates. Intervention, with appropriate maintenance treatments, at the appropria times, can greatly delay the deterioration cycle and consequently reduce the overall cost of maintaining the pavement. If timely Maintenance is not provided then reconstruction will become inevitable (see Fig. 9.1)

Flexible pavements are usually designed for a life of between 10 to 20 years. During this perk repairs such as patching, resealing, resurfacing with thin carpets and significant overlays are general needed. Even after expiry of the initial design life, complete reconstruction need not be inevitable if the ro has been properly maintained. Very often, the provision of an overlay, or surface dressing will be sufficie to significantly extend the life of a pavement.

This Chapter addresses the identification and treatment of a variety of defects encountered bituminous surfaces. It is, however, worthy of mention, at this stage, that the most cost effective maintenance treatment, and, perhaps, the one that is most often neglected, is one that is not applied directly to the bituminous layers at all. Poor road drainage and particularly failure to prevent ingress of water in the subgrade and into the lower pavement layers is considered to be the single greatest cause of road failures in India. Maintenance of the drainage system is usually a relatively low cost operation, and one which can significantly reduce the need for far more costly pavement repairs. Maintenance of the shoulders, often neglected, is also most important, so that water from the carriageway is able to access the line drains, a not accumulate at the edge of the carriageway.

9.2. Pavement Management System

Modern methods of highway maintenance make use of good management principles, which are invaluable aids in planning, and programming of maintenance operations. Many Pavement Management Systems (PMS) have been developed and are extensively used worldwide. A PMS is a computer packages. which facilitates advance planning of maintenance operations and optimal allocation of resources. Its main elements are:

1. A basic road data bank, built-up and updated periodically by road inventories and condition surveys.
2. A pavement performance model, which predicts the future performance of a given pavement system.
3. A transportation cost model, which calculates the road user costs for the given condition of the pavement.
4. Selection of intervention levels.
5. Prioritising the maintenance needs (renewal and overlay) for a given budget.

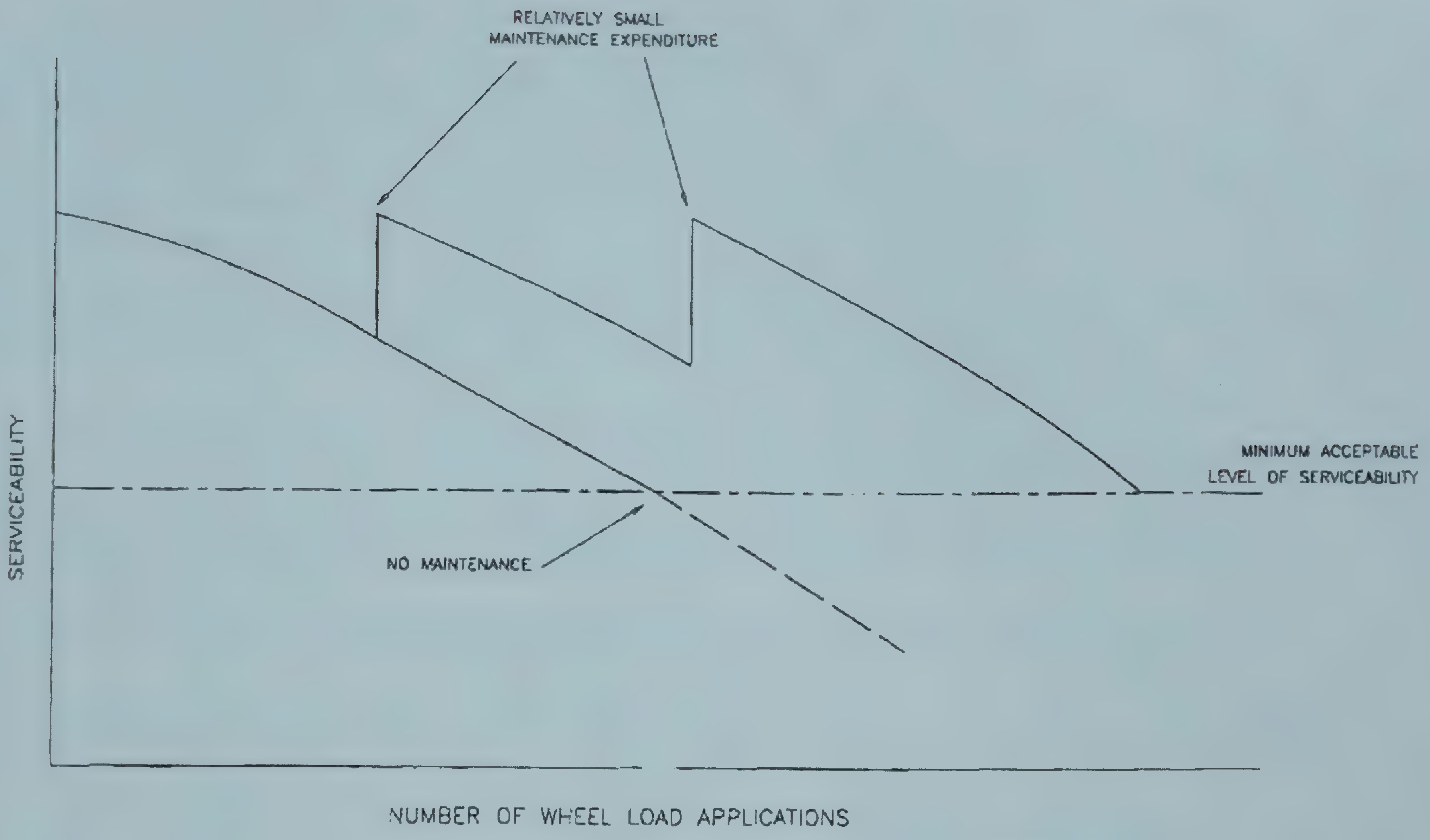


Fig. 9.1. Effect of Different Maintenance Strategies

It should be noted that for the survey data to be accurate, a stable system of longitudinal marking along the road is necessary to readily locate and identify the areas referred to in the condition survey. For example the person doing the visual inspection survey, must be able to accurately identify the chainage at any point on the road, in order that the maintenance team can readily find the location.

Clearly, maintenance of the road pavement alone is not, and should not be, the only concern of any roads authority. Therefore, in order to allow the wider issues to be addressed in a properly structured manner, it is usual for the Pavement Management System to be an integral part of a larger overall Road Maintenance Management System (RMMS).

9.3. Maintenance Planning in India.

Though the introduction of a PMS-based maintenance planning system is needed in India, and efforts in this direction are being made, the present practice of maintenance planning is based on a set of "Norms" which have been evolved for the National Highway network and State Roads. According to these, the requirements of routine maintenance and periodic renewals have been worked out taking into consideration factors such as :

1. Pavement width
2. Traffic
3. Rainfall
4. Terrain
5. Nature of surfacing

9.4. Maintenance Practice in India

At present, maintenance of pavements is looked after by the Public Works Departments (PWD), Zilla Parishads, Rural Engineering Organisations and the Border Roads Organisation. National Highways, which are owned by the Government of India, are maintained by the State PWDs who act as agents to the Central Government. The basic unit of maintenance is a Division under an Executive Engineer. The maintenance is generally done by a combination of departmental labour force (gang labour) and Contractors. The methods used are labour-intensive. There is much scope for mechanisation of the maintenance operations through the adoption of simple tools and equipment. Whatever the construction method, the PMS will identify the priorities on which the limited resources are most effectively used.

9.5. Classification of Maintenance Operations

Maintenance operations can be classified into three groups:

1. Routine Maintenance, which is the day-to-day work that is necessary to preserve and keep a pavement as close to as constructed condition as possible. It embraces activities such as pothole patching, sealing of cracks etc.
2. Periodic Maintenance, Which is the work carried out periodically every few years to prevent deterioration of a pavement It covers work such as applying a seal or thin resurfacing course.
3. Rehabilitation and' strengthening, which are substantially major works intended to restore or upgrade the pavement. The work covers thick overlays (above, say, 25 mm).

9.6. Assessing Maintenance Needs

Maintenance needs are assessed every year as part of planning of maintenance. The assessment is done on the basis of condition surveys, which can take various forms such as:

- Visual rating
- Roughness measurements
- Benkelman Beam Deflection Measurements, or preferably Falling Weight Deflectometer (FWD)
- Skid Resistance Measurements

Visual rating is a simple method of inspecting the pavement surface for detecting and assessing the type and severity of the damage. Manifestation of distress or damage occurs in the form of :

1. Rutting
2. Corrugations
3. Ravelling
4. Flushing
5. Potholes
6. Extent of repairs (patching) already carried out
7. Transverse cracking
8. Longitudinal cracking
9. Alligator cracking
10. Edge failure

In most instances, road inspections address all aspects of road condition, including the condition of shoulders, road drainage, road furniture etc., as well as the condition of the pavement. The items listed above are only those pertaining directly to the condition of the road pavement.

Although there are various methods of visual rating adopted by different agencies the world over, an essential requirement is to assess the various maintenance needs kilometer-wise all along the length of each road, as suggested in Fig. 9.2.

Pavement Serviceability Index (PSI) is one of the well-known rating methods, which takes into consideration surface characteristics such as the longitudinal profile, rut depth, area of cracking and patched area.

The riding quality of a pavement can be measured by a Bump Integrator which quantifies into physical terms, the overall surface condition of a pavement. It is thus a very useful tool in the hands of a maintenance engineer. The roughness values (in mm/km) recommended by the Ministry of Road Transport and Highways for roads with different types of surfaces are given in Table 9.1. It is good practice to take roughness measurements on the entire network of bituminised roads in the country, twice a year.

Table 9.1. Recommended Roughness Values for Roads in India in mm/km

Surface Type	Good	Average	Poor	Very poor
Bituminous concrete/SDBC	2000-2500	2500-3500	3500-4000	Over 4000
Premix bituminous carpet/MSS	2500-4500	4500-5500	5500-6500	Over 6500
Surface dressing	4000-5000	5000-6500	6500-7500	Over 7500

There are a number of means of assessing pavement deflection characteristics, of which the best known, in India, is the Benkelman Beam, also known as the Deflection Beam. Benkelman Beam deflection measurements may be interpreted to give an evaluation of the structural performance of a pavement. The rebound deflection gives an indication of the elastic property of a pavement. In newly constructed pavements deflections should be fully elastic and recoverable. On the other hand, old and deteriorated pavements may exhibit greater non-recoverable deflection.

Benkelman Beam measurements are not easy to interpret and may vary widely, from road to road, and even within a single length of road, with such factors as stiffness of pavement layers and their thickness, as well as their state of deterioration. Some authorities consider that the best use of the Benkelman Beam is to measure the deflections of pavements repeatedly, at intervals of time and, by comparing successive measurements, to identify the state of deterioration of the road.

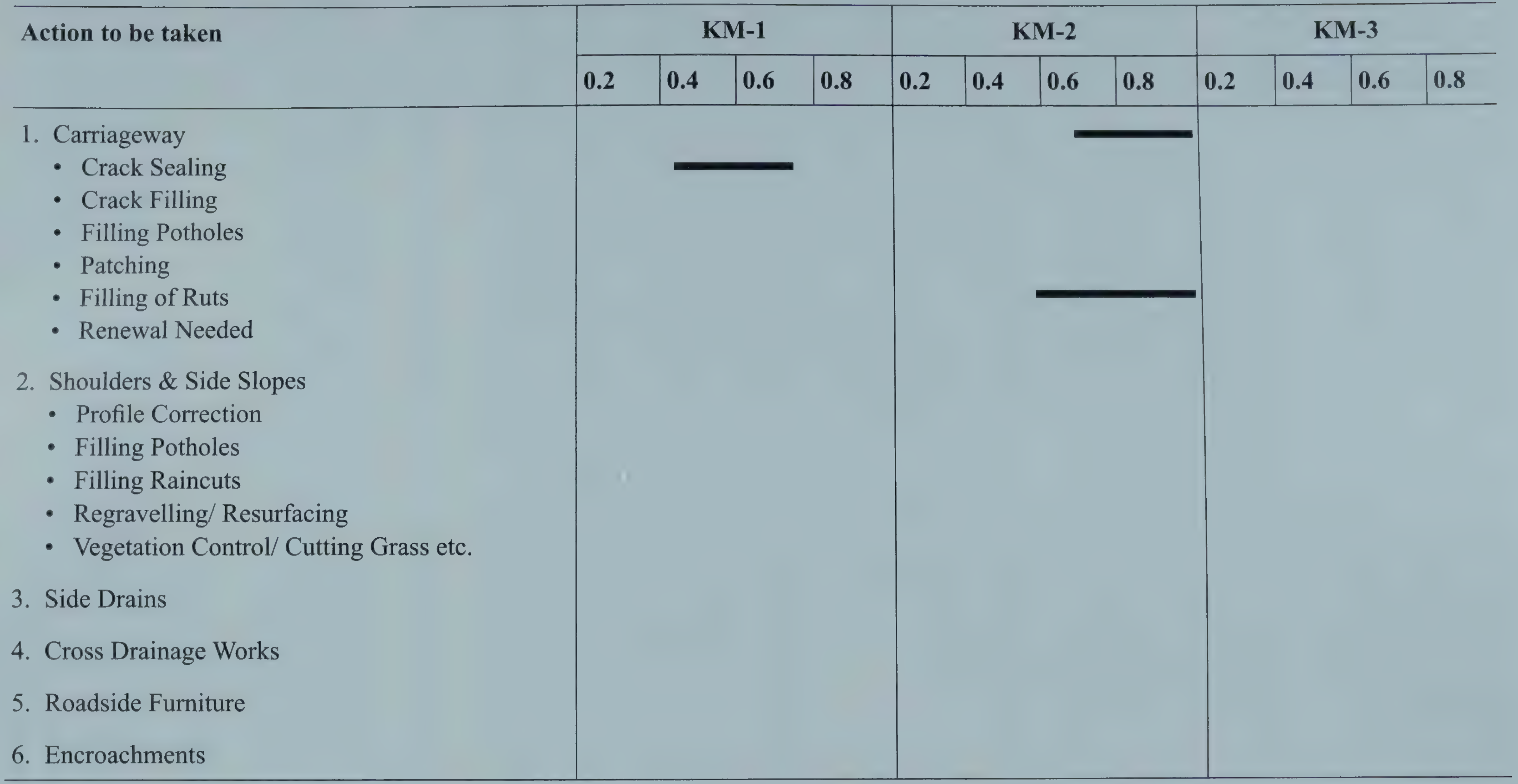
Benkelman Beam measurements are used, in India, as a means of designing the thickness of overlays, although the method is, at best, imprecise.

An alternative and much more accurate method for assessing residual life of the pavement, and also overlay design, is by way of a Falling Weight Deflectometer (FWD). This is a very quick and accurate test, but requires some capital investment in the small, trailer sized, equipment. The trailer is attached to a 4WD vehicle, and results recorded directly onto computer disc, for later analyses.

9.7. Surface Defects and their Rectification

9.7.1. General : Pavements tend, under continued trafficking, to lose their anti-skid properties as the texture wears out and the stone aggregates get polished. The skid resistance of a surface may also be reduced by bleeding, or "fatting up" of the road surface with excess bitumen. Many countries carry out skid-resistance measurements as part of their maintenance needs assessment. Those pavement sections which have lost their anti-skid properties may be treated with a fresh surface treatment.

KILOMETER-WISE ASSESSMENT OF MAINTENANCE NEEDS OF A BITUMINOUS PAVEMENT



Action to be taken	KM-1				KM-2				KM-3			
	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8
1. Carriageway							▬	▬				
• Crack Sealing		▬	▬									
• Crack Filling												
• Filling Potholes												
• Patching												
• Filling of Ruts							▬	▬				
• Renewal Needed												
2. Shoulders & Side Slopes												
• Profile Correction												
• Filling Potholes												
• Filling Raincuts												
• Regravelling/ Resurfacing												
• Vegetation Control/ Cutting Grass etc.												
3. Side Drains												
4. Cross Drainage Works												
5. Roadside Furniture												
6. Encroachments												

Fig. 9.2. Format for Kilometre-wise Assessment of Maintenance Needs

9.7.2. Fatty surface

Symptoms

A fatty surface occurs when the bituminous binder moves upward in the surfacing layer and collects as a film on the surface. The binder so collected becomes generally soft in hot weather and may be picked up and spread by the traffic. In cold or wet weather the surface is likely to be slippery and this con cause accidents. A typical "fatty" surface is shown in Fig. 9.3. This surface bitumen will always be mixed with a proportion of mineral fines.

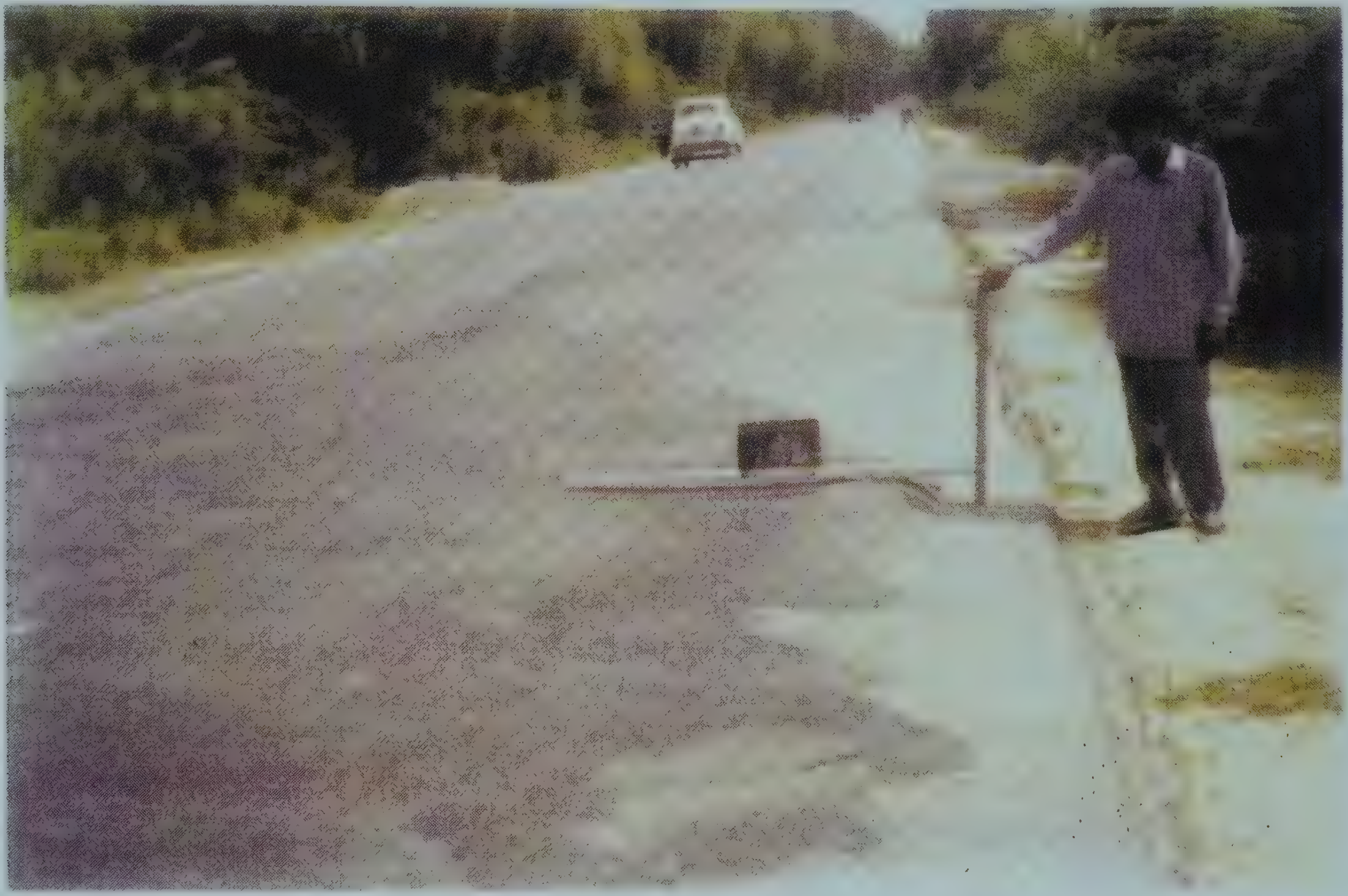


Fig. 9.3. A Typical "Fatty" or "Bleeding" Surface Showing Excessive Bituminous Binder on the Surface

This is not uncommon on surface dressed roads and, apart from skid resistance, need not be of any great consequence as regards the road structure However, if this should occur on an asphalt surface it can have most serious consequences On an asphaltic concrete surface flushing or bleeding indicates that the air voids have reduced to near zero, to a point where plastic deformation in the surface might be expected. Thus rutting and/or corrugations are likely to form, for which the only remedy is to rake up and discard this surfacing, and replace with a new surface.

Causes

The causes for a fatty surface are:

1. poor mix design; variations of the production mix from the design
2. Loss of cover aggregates in surface dressing
3. non- uniform spreading of cover aggregates in surface dressing
4. Excessive application of binder in surface dressing and liquid seal coat
5. poor quality of aggregates in surface dressing leading to their fracture, breakdown and eventual loss

6. Graded cover aggregates with particles so small and/or flaky that they are covered by the binder

7. Too heavy a prime or a tack coat

8. More compaction in the road (e.g by excessive axle loads) than allwed for in the design (e.g. refusal density not used)

Treatment

surface dressed Areas

(a) if the bleeding is fairly uniform and the surface is free from irregularaties, application of cover aggregates or sand (sand-blotting or sand-blinding) would be successful. Coarse sand or aggregate 9 mm and down can be used; these should be clean and angular and may be heated if necessary.

(b) surfacing with a thin layer of open-graded premix surfacing with appropriate bitumen content may absorb the excess binder.

(c) A liquid seal coat, with special care taken to select the rate of application of the binder and the quantity and size of cover aggregates, can also be effective.

Asphaltic Concrete or Premix Surfaces

If bleeding occurs on an asphaltic concrete or pre-mix surface, and as a consequence deforms, the only solution is removal and replacement. This might be achieved by milling , or otherwise by total excavation.

9.7.3. Smooth surface

Symptoms

A smooth surface has a very a low skid resistance value and becomes very slippery when wet. Such a condition invites accidents, especially on gradients, bends, and intersections. A typical smooth surface resulting from the polishing of aggregates is shown in Fig. 9.4.

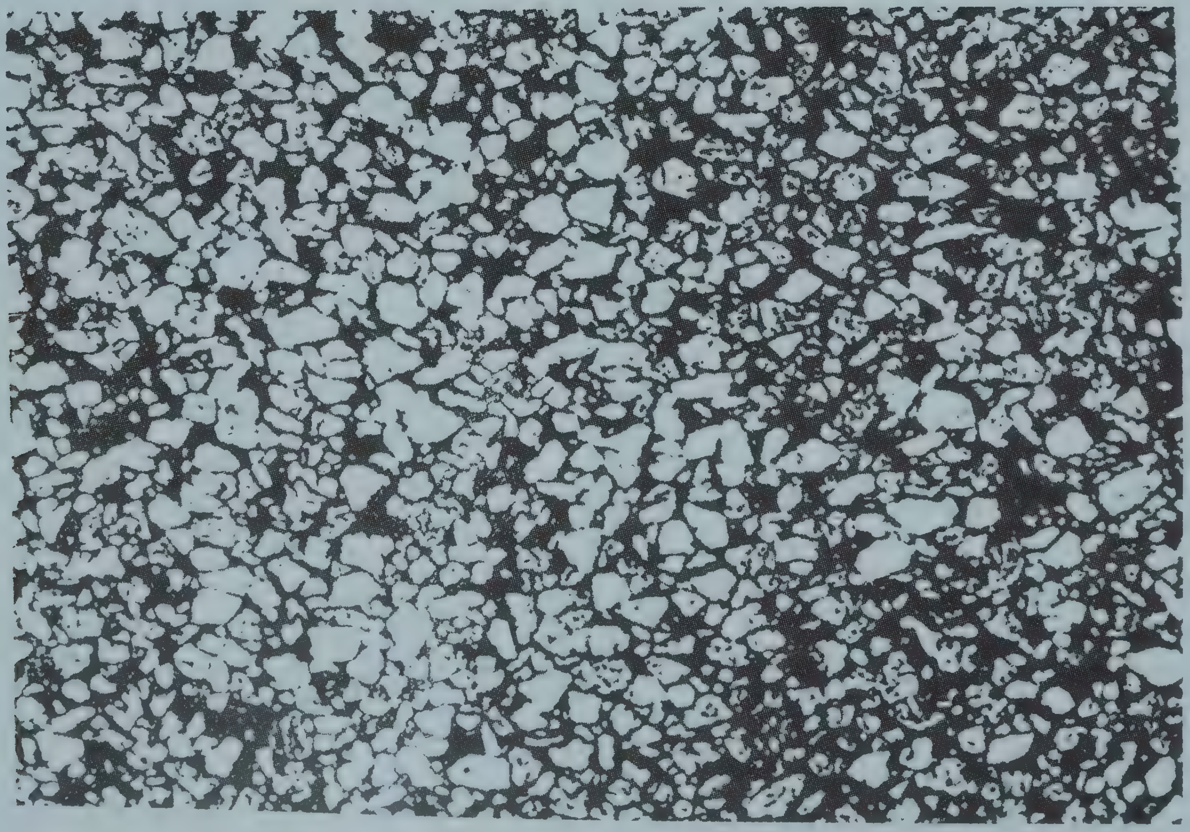


Fig. 9.4. A Smooth Surface Resulting from Polishing of Aggregates

Causes

A primary cause for a smooth surface is the polishing of aggregates under traffic. Also a fatty surface is a smooth surface.

Treatment

The rectification consists of resurfacing with a surface dressing course and Type 'A' seal coat or a premix carpet. Care should be take to select hard and angular aggregates, which have proven non-polishing polishing characteristics. The carpet can be an open-graded mix where traffic is light. A slurry seal can also be used to impart anti-skidding texture with the use of special aggregate.

9.7.4. Streaking

Symptoms

Streaking is characterised by the appearance of alternate lean and fatty lines of bitumen usually in a longitudinal form.

Causes

Longitudinal streaking occurs when alternate longitudinal strips of surface contain different quantities of bitumen due to a non uniform application of bitumen across the surface when surface dressed. Some of the more common causes of this type of streaking are mechanical faults, improper or poor adjustment, and careless operation of bitumen distributors. These streaks can also be formed as a result of applying the bituminous binder at too low a temperature - a temperature at which bitumen is too viscous to fan out properly from the nozzles on the spray bars.

Although much less common, transverse streaking may result from mechanical faults or poor operation (stopping and starting) of the distributor.

Treatment

Streakiness is not easy to rectify by additional treatment, and it is therefore more usual to remove the streaked surface and apply a new surface treatment Therefore, much emphasis should be placed on its prevention and when mechanical equipment is used for spraying of bitumen, manufacturer's recommendations of the working of bitumen distributor should be carefully adhered to.

9.7.5. Hungry or lean surface

Symptoms

A "hungry" surface (Fig. 9.5) is characterised by the absence of sufficient matrix (bitumen and fine aggregates) between the coarse aggregate particles or by the loss of aggregates from the surface. This surface is prone to "ravelling" , where the stone particles are picked out by traffic, and is thus also prone to potholing, and advanced form of ravelling.

Causes

A hungry surface may result from the use of insufficient bitumen in the surfacing or the use of absorptive aggregates. It does not usually occur on surface dressed area, normally being limited to pre-mix surfacings. Loss of

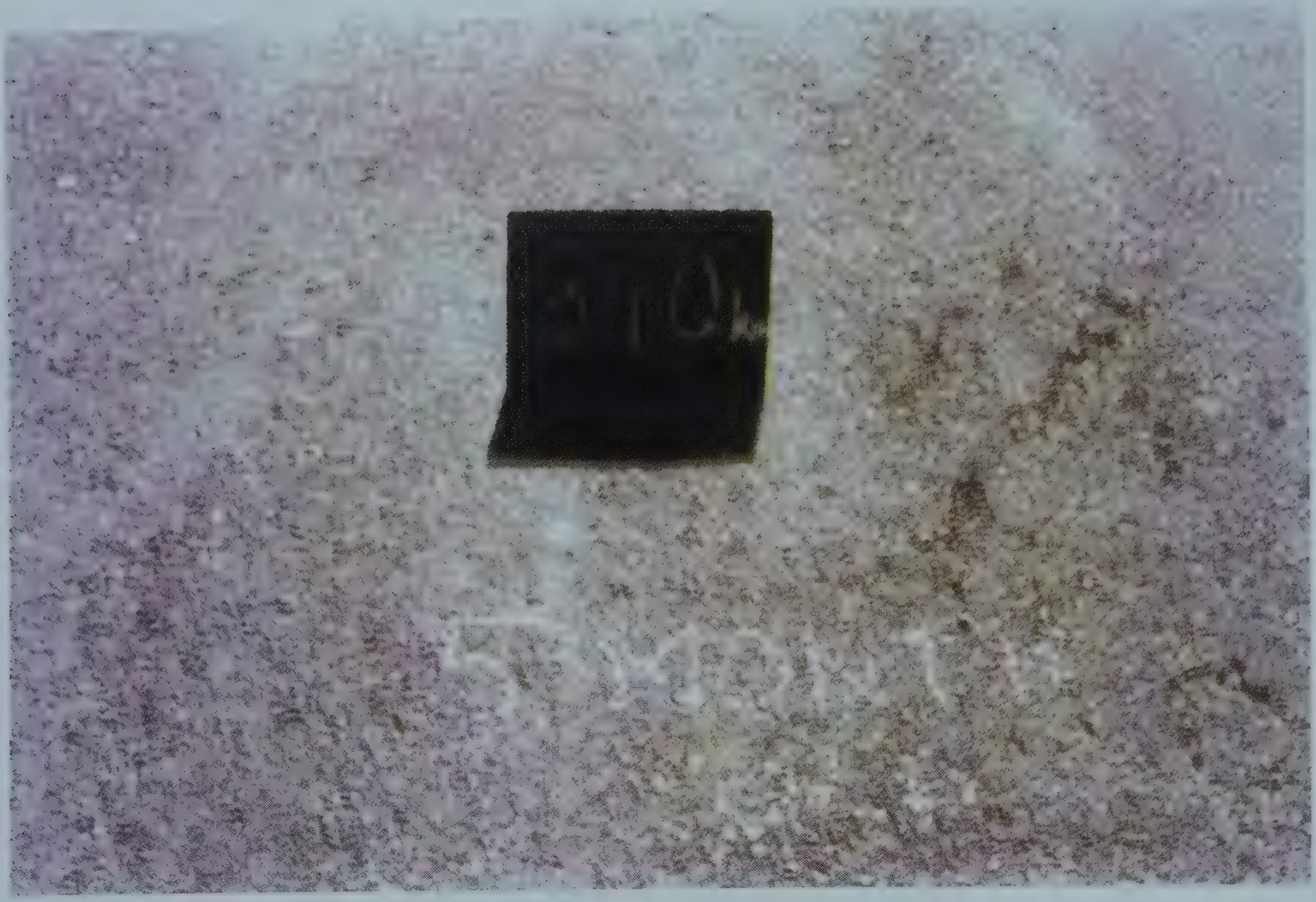


Fig. 9.5. A "Hungry Surface"

bitumen from the top surface can result from the action of traffic on an old surface where the bitumen is well oxidised. Normally the other cause is in the mix design, or mixing procedure when the material was laid.

Treatment

The normal remedial measures for a lean surface is after treating any potholes, a carefully designed surface dressing. Alternatively a slurry seal may be used as a repair measure. It is applied in an average thickness of 2-5 mm.

As an emergency repair. a fog seal may be used.

9.7.6. **Cracks:** Their rectification and prevention

9.7.6.1. General: A common defect in bituminous surfaces is the formation of cracks. The crack pattern can, in many cases, indicate the cause of the defect. As soon as cracks are observed, it is necessary to study the pattern in detail so as to arrive at the cause. Immediate remedial action should be taken thereafter because of the danger of ingress of water through the cracks and of the formation of pot-holes and ravelling. Cracks cannot be properly observed from moving vehicles and inspection on foot is always desirable. The common types of cracks are briefly discussed below:

9.7.6.2. Hair- line cracks

Symptoms

Hair- line cracks appear as short and fine cracks (Fig.9.6) at close intervals on the surface.

Fig. 9.6. "Hair Line Cracks" on the surface

Causes

These cracks are caused by:

1. Insufficient bitumen content
2. Excessive fines at the surface
3. Improper compaction, over-compaction when the supporting layer was unstable, or compaction of a mixture when too hot

Hair-line cracking can sometimes be observed on a newly laid asphalt surface, under the breaking roller. This can sometimes be seen at commencement of work, when the steel drums/wheels are cold. These cracks will normally close up under the PTR. If they are still visible after rolling is complete, the mix design and workmanship techniques should be closely scrutinised. It has been known for the cracks to close up under traffic within a few days, and the surface prove satisfactory, but it is necessary to establish the cause, and instigate remedial measures, as there is something obviously amiss.

9.7.6.3. Alligator cracks

Symptoms

These appear as interconnected cracks forming a series of irregular small blocks up to 100 mm across, which resemble the skin of an alligator (Fig 9.7). They usually appear in localised areas, up to 10 m dia.

Causes

Alligator cracks are due to one or more of the following factors:

1. Excessive deflection of the surface over unstable subgrade, sub-base or base of the pavement, particularly in the wheel tracks. The unstable conditions in the subgrade or lower layers of the pavement may often arise from ingress of water.
2. Excessive overloads by heavy vehicles or inadequate pavement thickness, or both.
3. Brittleness of the binder either due to ageing of binder or initial over-heating might cause fine cracks of the alligator pattern but there will be no deflection of the surface. These cracks are sometimes called 'crazing'.

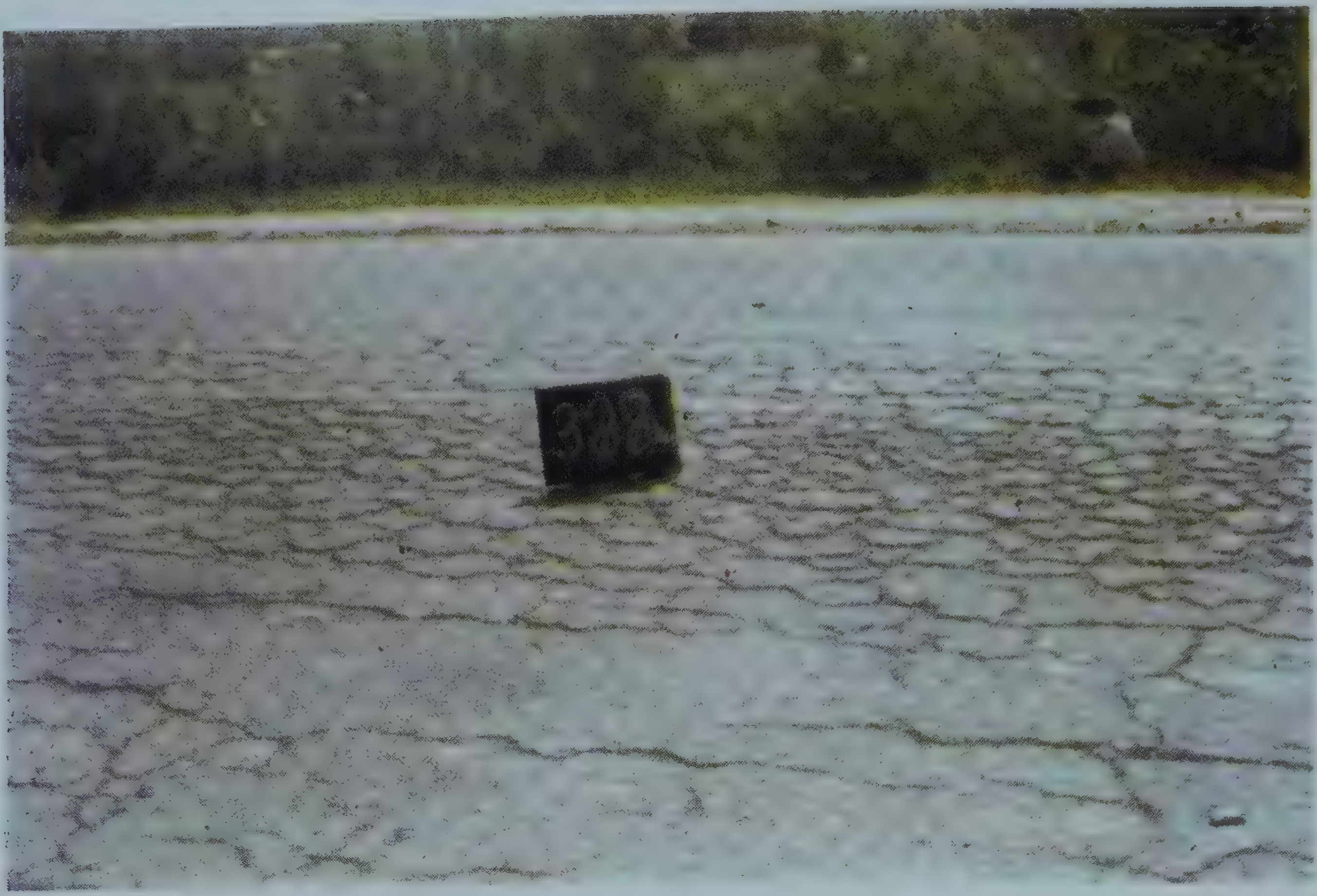


Fig. 9.7. Severe "Alligator Cracking"

When alligator cracking is accompanied by visibly detectable movement of the road surface, under passing traffic, it is surely to be taken as a good indication that the pavement will have to be completely reconstructed. Where alligator cracking occurs in the most commonly trafficked wheel-tracks' and where perceptible uplift of the surface of the road can be observed on either side of the wheel-tracks, it is usually an indication that the cause of the failure is relatively shallow Where alligator cracking in the major wheel-tracks' is accompanied by depression of the road surface with no discernible corresponding uplift, it is usually an indication of a more deep-seated failure.

In any event, alligator cracking can be taken as a sure sign of base failure. Subsequent investigations should aim to establish at what level the failure has occurred, and why. This will determine what remedial measures are necessary.

9.7.6.4. Longitudinal cracks

Symptoms

These cracks appear, more or less, on a straight line, along the road (FIg. 9.8.). These cracks may appear either at the joint between the pavement and a sealed shouklder, or at the joint between tow paving lanes.

Causes

1. The cracking at the pavement-shoulder joint may be due to alternate wetting and drying beneath the shoulder surface owing to poor drainage or due to depressions in the pavement edge which allow water to stand and seep through the joint. Shoulder settlement or trucks passing over the joint, may also cause these cracks.
2. The lane joint crack is caused by a weak joint between adjoining spreads in the layers of the pavement. Differential frost heave along the centre line may also be one of the causes. Longitudinal lane cracks have a tendency to occur where the joints in the successive pavement layers have not been staggered.

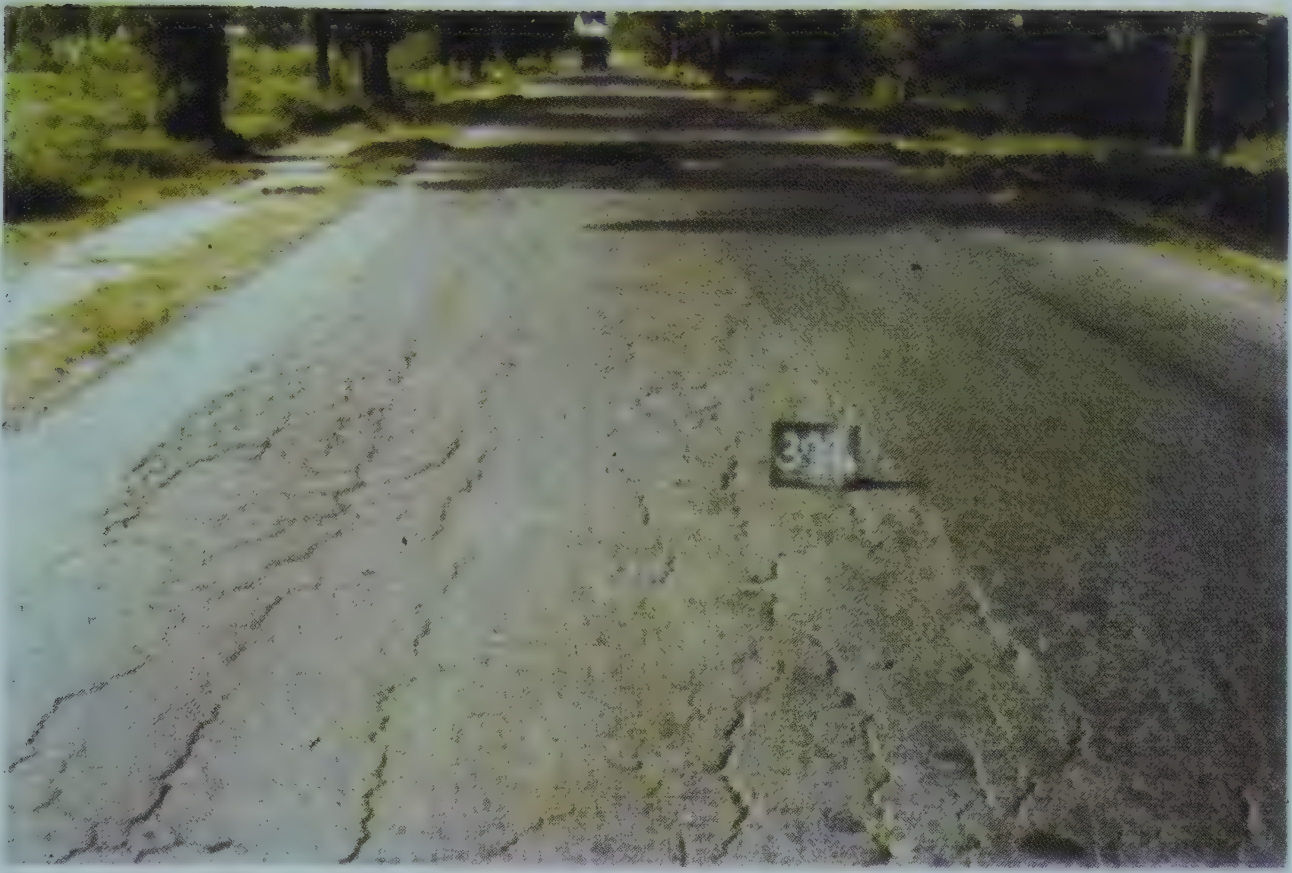


Fig. 9.8. Typical "Longitudinal Cracks" Along the Road

9.7.6.5. Edge cracks

Symptoms

Edge cracks (Fig. 9.9) are formed parallel to the outer edge of the pavement usually 0.3-0.5. m inside from the edge. At times some transverse cracks are seen to branch out from the edge cracks towards the shoulder. In the advanced stages the cracking leads to "crippled" edges, and spalling, where the repair can no longer be treated as a crack repair, but requires excavation and complete replacement of the affected area.

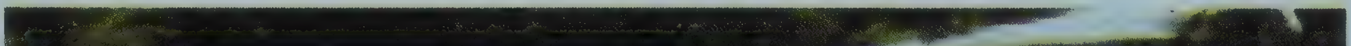


Fig. 9.9. Edge Cracks

Causes

These cracks are caused by:

1. Lack of lateral support from the shoulder.
2. Settlement or yielding of the underlying material.
3. Inadequate surface drainage, especially during flooding conditions. The correct level and grading of the shoulder plays an important part in this defect.
4. Shrinkage due to drying out of the surrounding and underlying earth, caused by roots of tress or bushes close to the pavement edge or seasonal moisture changes.
5. Highly expansive soils are particularly prone to shrinkage when moisture dries out.
6. Frost heave.
7. Inadequate pavement width forcing traffic too close to the edge of the edge of the pavement.
8. Non-provision of extra width of pavement on curves.

9.7.6.6. Block cracking

Symptoms

These cracks appear in the form of "blocks" as shown as shown in Fig.9.10.

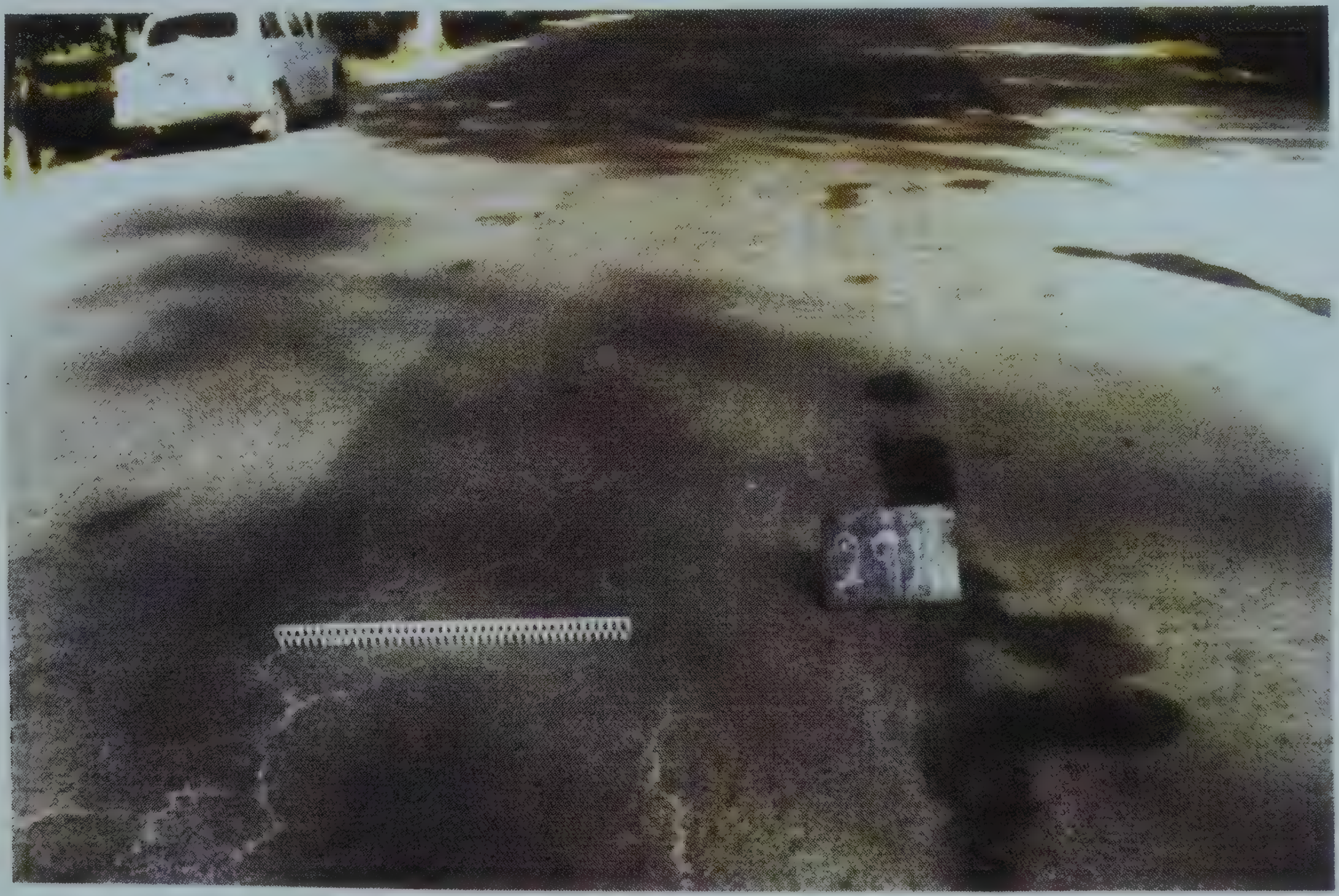


Fig. 9.10. Block Cracking

Causes

Longitudinal cracks when widely spaced and associated with transverse cracking constitute block cracking. These often occur in old brittle surfaces, where the bituminous surfacing has lost it's elasticity , and cracks due to the thermal movement, particularly in colder weather conditions, when the bitumen is at it's most brittle.

9.7.6.7. Reflection cracks

Symptoms

Reflection cracks(Fig 9.11) are the sympathetic cracks that appear in the bituminous surfacing over joints and cracks in the pavement underneath. The pattern may be longitudinal, transverse, diagonal or block. They occur most frequently in overlays on cement concrete pavements or on cement-soil bases. They may also occur in overlays or surfacings on flexible pavements where cracks in the old pavement have not been properly repaired. Another condition under which reflection cracks can occur is when a pavement is widened and the entire pavement is surfaced. The location of the crack will then be on the junction between the old pavement and the widened strip.

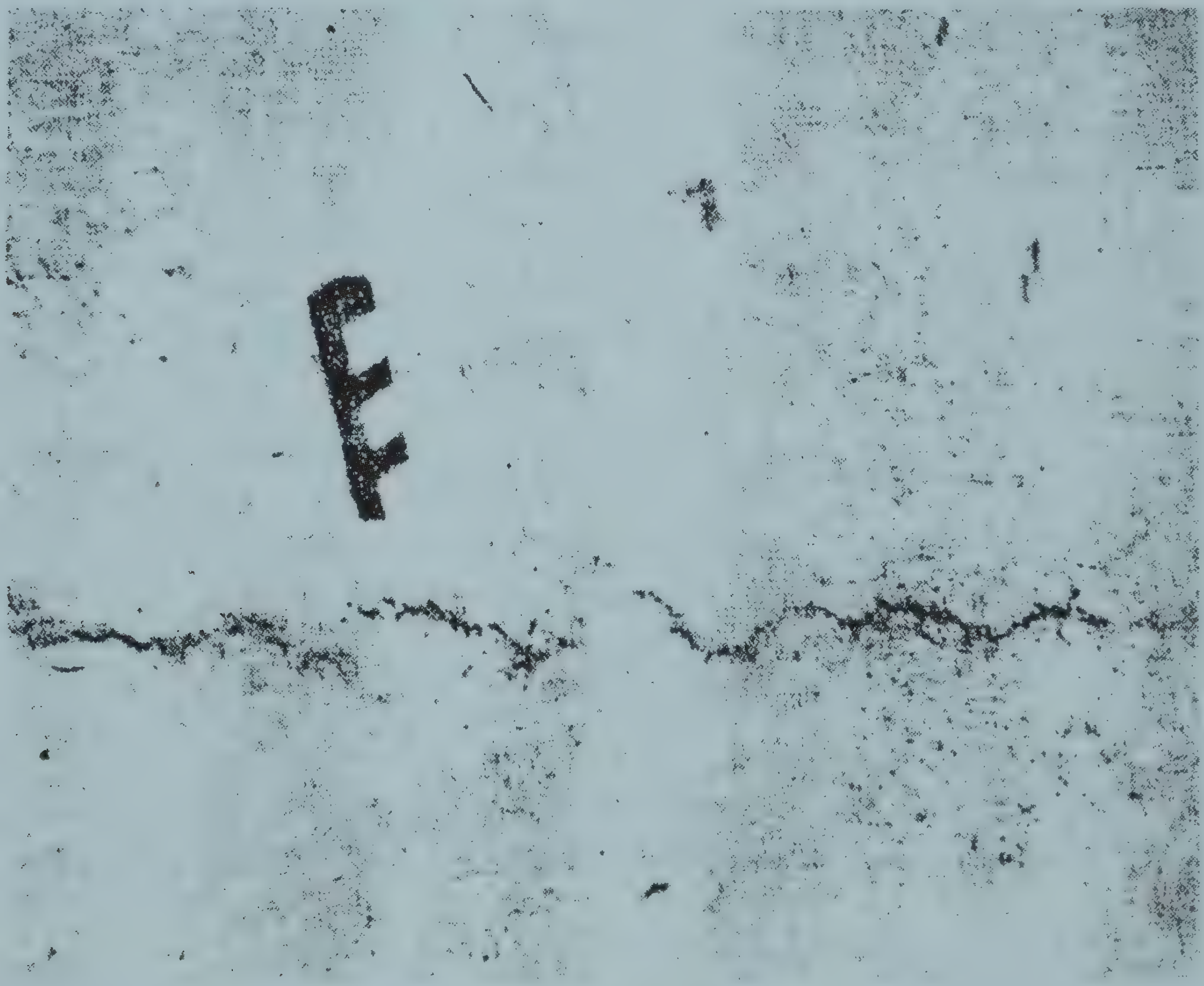


Fig. 9.11. Reflection Cracking

In some cases reflection cracks are merely unsightly, but frequently they deteriorate and the riding quality of road is affected. These cracks can allow water to enter the underlying pavement and the subgrade and cause further damage.

Causes

Reflection cracks are due to vertical or horizontal movements at joints and cracks in the pavement layer underneath. These movements may be caused by deflection under load, expansion and contraction or shrinkage and swelling below the old pavement.

9.7.6.8. Treatment of cracks: Details have been covered in para 8.2.4 ‘Preparation of surface’.

9.7.6.9. Prevention of cracks: In order to inhibit the propagation of cracks, two of the preventive measures which can be successfully adopted are the provision of :

(a) Stress Absorbing Membrane (SAM), laid over the cracked road surface, together with a covering of aggregate chips. The provision of SAM is known to extend the life of the pavement before any major treatment is carried out SAM can be laid as a single coat or a double coat.

(b) Stress Absorbing Membrane Interlayer (SAMI), a layer which is applied to a cracked pavement surface but which is followed (within12months) the application of an overlay course A SAMI may be a material similar to that used for a SAM, alternatively it may consist of a bitumen impregnated geotextile.

The quantity of materials required for 10 sqm of road surface for stress absorbing membrane are given in Table 9.2.

Table 9.2 Quantity of Materials Required of 10 sqm of Road Surface for Stress Absorbing Membrane

Sl. No.	Type and Width of Crack	Specification of SAM to be applied	Quantity of binder kg/10m^2	Quantity of chipping
1.	Hair cracks and map cracks upto 3mm width	Single coat SAM or 2nd coat of two coat SAM	8-10	0.10m^3 of 5.6 mm chips
2.	Map cracks or alligator cracks 3 mm to 6 mm width	Single coat SAM	10-12	0.11 m^3 of 5.6 mm chips
3.	Map cracks or alligator cracks 6 mm to 9 mm width	Two coat SAM 1st coat	12-14	0.12 m^3 of 5.6 mm and 11.2 mm chips in 1:1 ratio
		2nd coat	8-10	0.10 m^3 of 5.6 mm chips
4.	Cracks above 9 mm width and cracked area above 50 per cent	Two coat SAM 1st coat	14-16	0.12 m^3 of 11.2 mm chips
		2nd coat	8-10	0.10 m^3 of 5.6 mm chips
5.	All types of cracks with crack width below 6 mm	Single coat SAM as inter layer	8-10	0.10 m^3 of 5.6 mm chips
6.	All types of cracks with crack width above 6 mm	Single coat SAM as inter layer	10-12	0.10 m^3 of 11.2 mm chips
7.	Bitumen Impregnated Geotextile[1]			

Note: [1]Binder quantities for bitumen impregnated geotextile shall be in the range 0.9 to 1.2 litres/m^2 Binder quantities outside this range are permitted according to the geotextile manufacture 's instructions and subject to the agreement of the Engineer.

9.7.6.10. Methodology for laying single coat SAM [1]

(a) **Preparation of modified Bitumen :** The required quantity of the appropriate penetration grade of paving bitumen should be taken in a tar boiler fitted with paddle stirrer or pressure distributor at 160°C to 170°C. Then, calculated quantity of polymer modified bitumen concentrate (SAM-C) in the form of cakes/paste/pellets should be added to heated bitumen with vigorous agitation or circulation of contents till the two materials are mixed uniformly. Either the modified bitumen can be blended at the site, as described above or supplied hot in tankers or if supplied in drums, should be agitated in melted condition for 10 15 minutes, be for use Tests for penetration, softening point, separation and elastic recovery should be conducted at site a lot of 5 tonne polymer modified bitumen (IRC:SP:53.) Where latex or Dry Rubber powder is used as a modifier, the indicative dose is 2 to 4 per cent by weight of bitumen, while with Styrene Butadiene Styrene Block Copolymer (SBS) or Styrene Butadiene Rubber (SBR) the indicative dose is 3 to 5 per cent by weight of bitumen. Where reclaimed rubbers are used as modifiers, a higher dose level of 10 to 12 per cent by weight of bitumen is indicated. In case of proprietary Products, which may contain a blend of different polymeric additives, test reports and cost effectiveness should be the basis for selection.

(b) **Application of modified bitumen as Membrane :** The modified bitumen conforming to he specified requirements (IRC:SP:53) should be heated to 160 to 170°C and sprayed on the prepared, clean and dry surface (see Para 8.2.4).

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[1] New Specification: Clause 522 of Ministry's Specifications

uniformly, using a pressure having self-heating arrangement and spray nozzle bar capble of spraying uniformly at the rates given in Table 9.1.

(c) Application of Cover material : Spreading of the cover aggregate preferably by mechanical gritter should immediately follow the spraying of polymer modified bitumen It must be ensured that the stone chips are applied within a couple of minutes of binder being sprayed at any one location along the spray line Also, the capacity for rolling should should be such that first pass of roller can be made within 5 to 10 minutes of the blended material sprayed. Thorough sweeping to remove all excess chippings is necessary.

(d) Rolling : Rolling should be carried be carried out with pneumatic/steel tyred self propelled roller, having a minimum operating weight of 8 to 10 tonnes. Rolling should be continued till all cover aggregate particles are firmly embedded in bituminous material, but carefully avoiding excessive rolling which can lead to crushing of aggregate.

9.7.6.11. Methodology for laying two-coat SAM[1] : The second coat of SAM should be applied immediately after the laying of first coat; however, under certain special conditions, if it has to be delayed, it must be applied within 90 days of the first coat application.

Prior to application of the second coat of polymer modified bitumen, the surface should be cleaned as described earlier under 'preparation of Surface' in para 8.24 and any loose or foreign matter removed. After getting the surface irregularities corrected and surface brought to proper camber and gradient, a second coat of polymer modified bitumen heated to appropriate temperature should be uniformly sprayed preferably with distributor at the rate given in Table 9.1 for the second coat.

Immediately after application of binder, cover material of 5.6 mm size aggregate at the rate of 0.09 to 0.11 m^3 per 10 m^2 should be spread uniformly preferably by a mechanical grit spreader so as to cover the surface completely, if two coat SAM is to be used as overlay. If however, a new overlay is to be provided and the two-coat SAM is to be used as an interlayer (SAMI), cover material should be used at the rate of 0.08 to 0.10 sqm leaving about 25 per cent of surface unchipped to allow better binding between SAM and the overlay.

After the aggregate is uniformly spread, rolling should be carried out with a 6 to 8 tone roller preferably displaying pneumatic tyred or vibratory rubber drum-type rollers, till the particles are firmly embedded in the bituminous layer. When finished, the surface should show no variations greater the surface should show no variations greater than 6mm over a 3m length. The road may be opened to traffic two hours after rolling, but limiting the speed to 20 km/hr till the following day.

9.7.6.12. Methodology for laying SAMI[2] : A Stress Absorbing Membrane Interlayer (SMI) may be provided with a material similar to that used for SAM and the methodology for laying SAMI will be the same as for SAM, as outlined in the above paras. Where SAMI consists of a bitumen impregnated geotextile, the guidelines on construction with geosynthetics provided in par 8.5.2. (B). Chapter 8 of this manual may be followed. It must be kept in mind that cutback bitumens should not be used with polypropylene geotextiles since the solvent reacts with the polymer at high temperatures. The quantity of bituminous emulsion (CRS-2 or CRS-lh) to be sprayed over the prepared existing pavement should be in the range of 0.2 to 2.3 litres/m^2 depending on the porosity of the existing pavement and the absorbency of the geotextile.

9.8. Surface Deformations and their Rectification

9.8.1. General : Any change in the shape of the pavement from its original shape is a deformation. It may be associated with slippage, rutting, etc, discussed below. The treatment measures aim at the removal.

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[1] New specification: Clause 522 of Ministery's Specifications

[1] New specification: Clause 522 of Ministery's Specifications

of the cause, and bringing it to the original level by fill material or by removing the entire affected part and replacing it with new material.

9.8.2. Slippage

Symptoms

Slippage is the relative movement between the surface layer and the layer and the layer beneath This distress usually occurs when there is a low-strength surface mix or poor bond between the surface and the next layer of the pavement structure it is characterised by the formation of crescent-shaped cracks (Fig 9.12). Slippage cracks are produced, when braking or turning wheels cause the pavement surface to slice or deform.

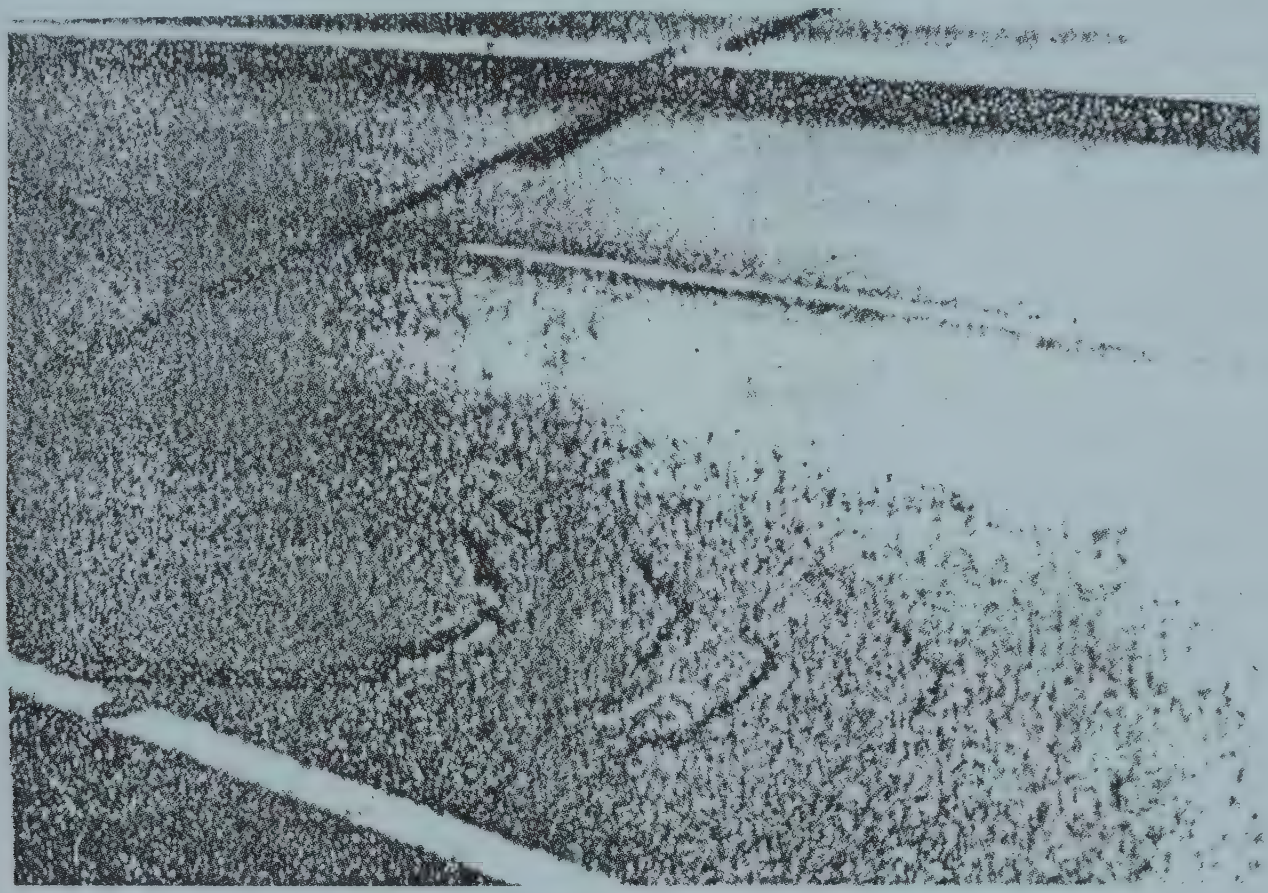


Fig. 9.12. Slippage Cracks

Causes

Slippage is caused by

1. Unusual thrust of wheels in a particular direction
2. Omission or inadequacy of tack coat or prime coat
3. Lack of bon between the surface and the lower cause caused by a layer of fine dust, moisture of both
4. Failure of bond between two layers due to excessive deflection of the pavement.

Treatment

Rectification consists of removing the surface layer around the area the area up to the point where good bond between the surfacing and the layer underneath exists and patching the area with premix material after a tack coat.

9.8.3. Rutting

Symptoms

Rutting is a longitudinal depression or groove in the wheel tracks. The ruts are usually of the width of a wheel path Swerving from a rutted wheel path at high speed can be dangerous Accumulation of water in the depressions can cause skidding. Rutting may or may not be accompanied by adjacent of the road surface, which may give some indication of the depth of the source of failure. A view of rutting can be seen in Fig 9.13.

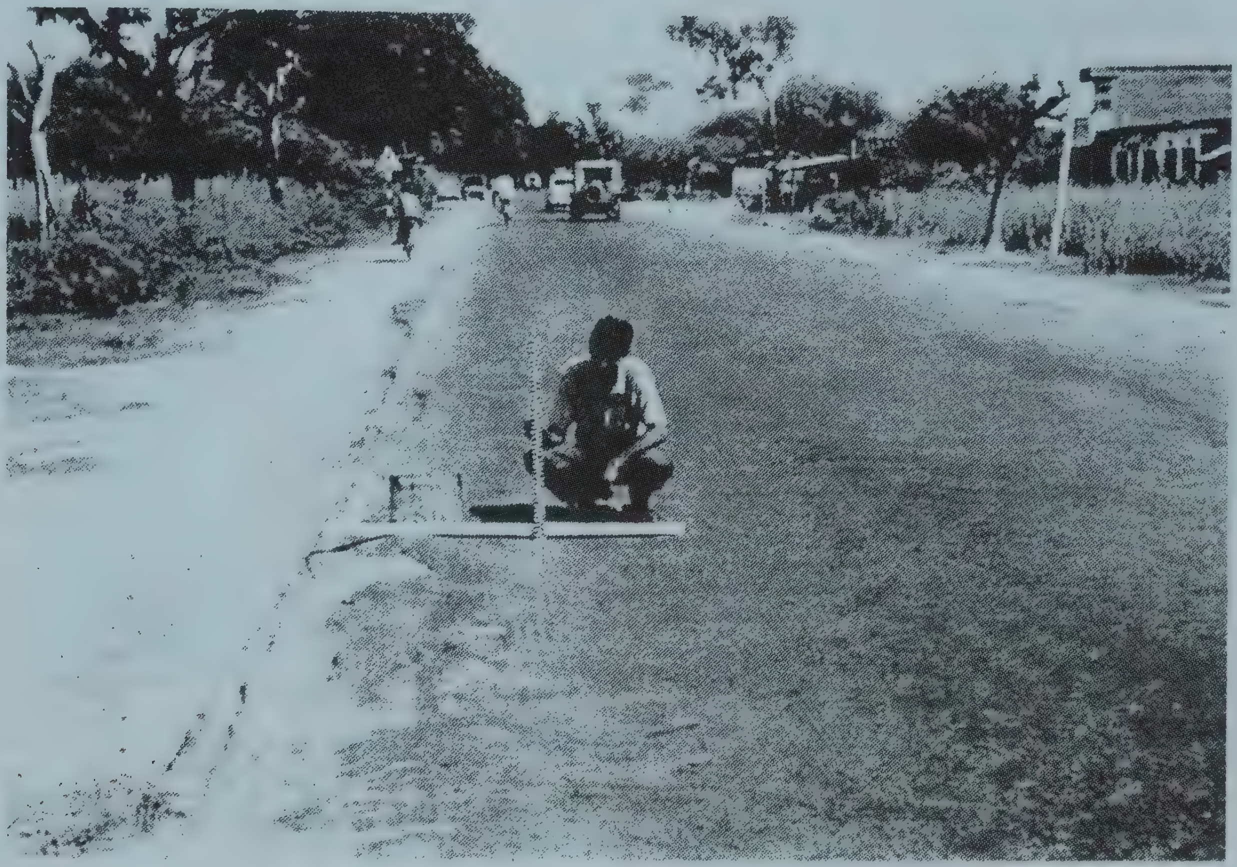


Fig. 9.13. Rutting under Wheelpath

Causes

The causes of rutting are the following :

1. Heavy channelled traffic.
2. Inadequate compaction of the mix at the surface or in the underlying courses during construction
3. Improper mix design, lacking in stability of the mix to support the traffic and leading to plastic movement laterally under traffic .
4. Week pavement
5. Incidence of high contact stress caused by heavy bullock-cart traffic.
6. Intrusion of subgrade clay into the sub base course due to shear failure or pumping.
7. Aggregates of surface dressing being pressed into the lower supporting bituminous layer.

Treatment

Details have been provided in para 8.2.4. for ‘Preparation of Surface’.

9.8.4. Corrugations

Symptoms

Corrugation is the formation of fairly regular undulations (ripples) across a bituminous surface (Fig 9.14). They are usually shallow (about 25 mm) and are different from the larger depressions caused by weakness in the lower layers of the pavement or the subgrade. The spacing of the waves is around 3 m. The corrugations can be a source of discomfort to the motorists and can become a hazard if allowed to become severe.

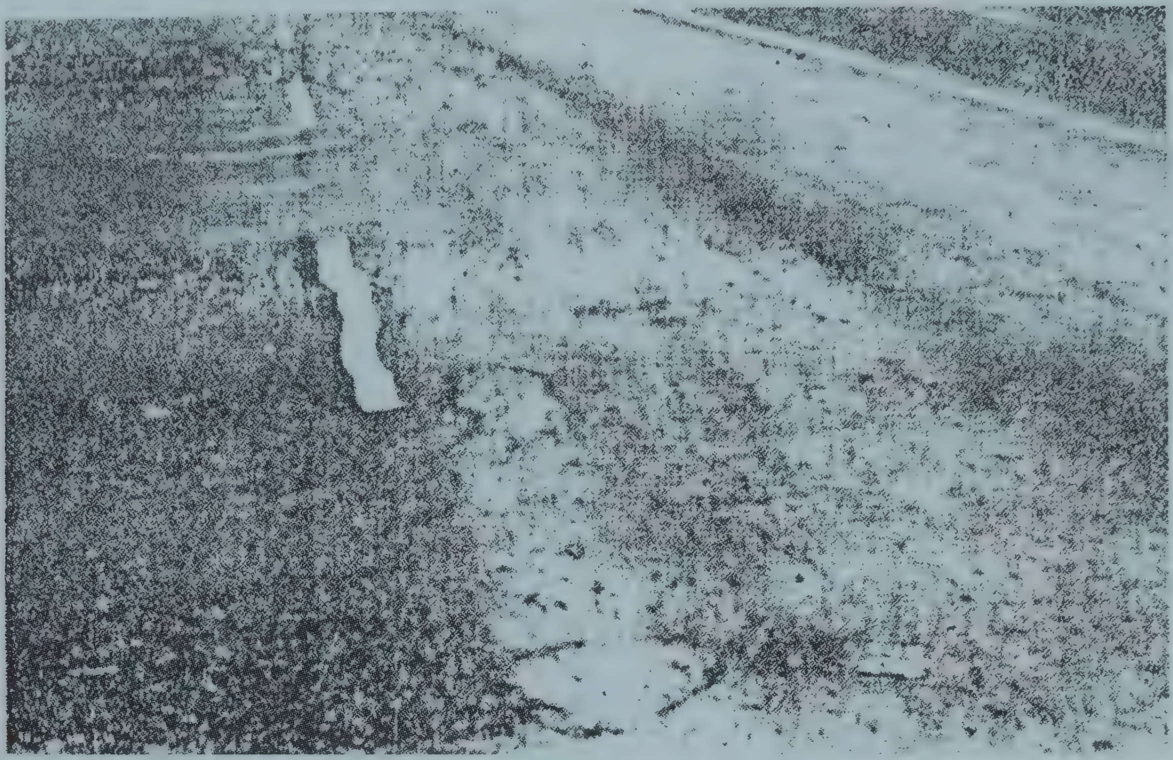


Fig. 9.14. Regular Undulation Across the Bituminous Surface Forming Corrugation

Causes

Corrugations are due to the following causes:

1. Lack of stability in the mix (excessive binder, high proportion of fines, too round or too smooth textured coarse or fine aggregate, too soft a binder)
2. Oscillations set up the vehicle springs can cause alternative valleys and ridges.
3. Faulty laying of surface course.

Treatment

Details have been provided in para 8.2.4. for ‘Preparation of surface’.

9.8.5. Shoving

Symptoms

Shoving is a form of plastic movement within the layer resulting in localised bulging of the pavement surface. Shoving occurs characteristically at points where traffic starts and stops (Intersections, busy bus-stops), on hills where vehicles accelerate or brake on grades and on sharp curves. The first indication of shoving is the formation of slippage cracks which are crescent shaped cracks with the apex of the crack pointing in the direction of the shove. A view of a road where shoving has taken place is shown in Fig 9.15.

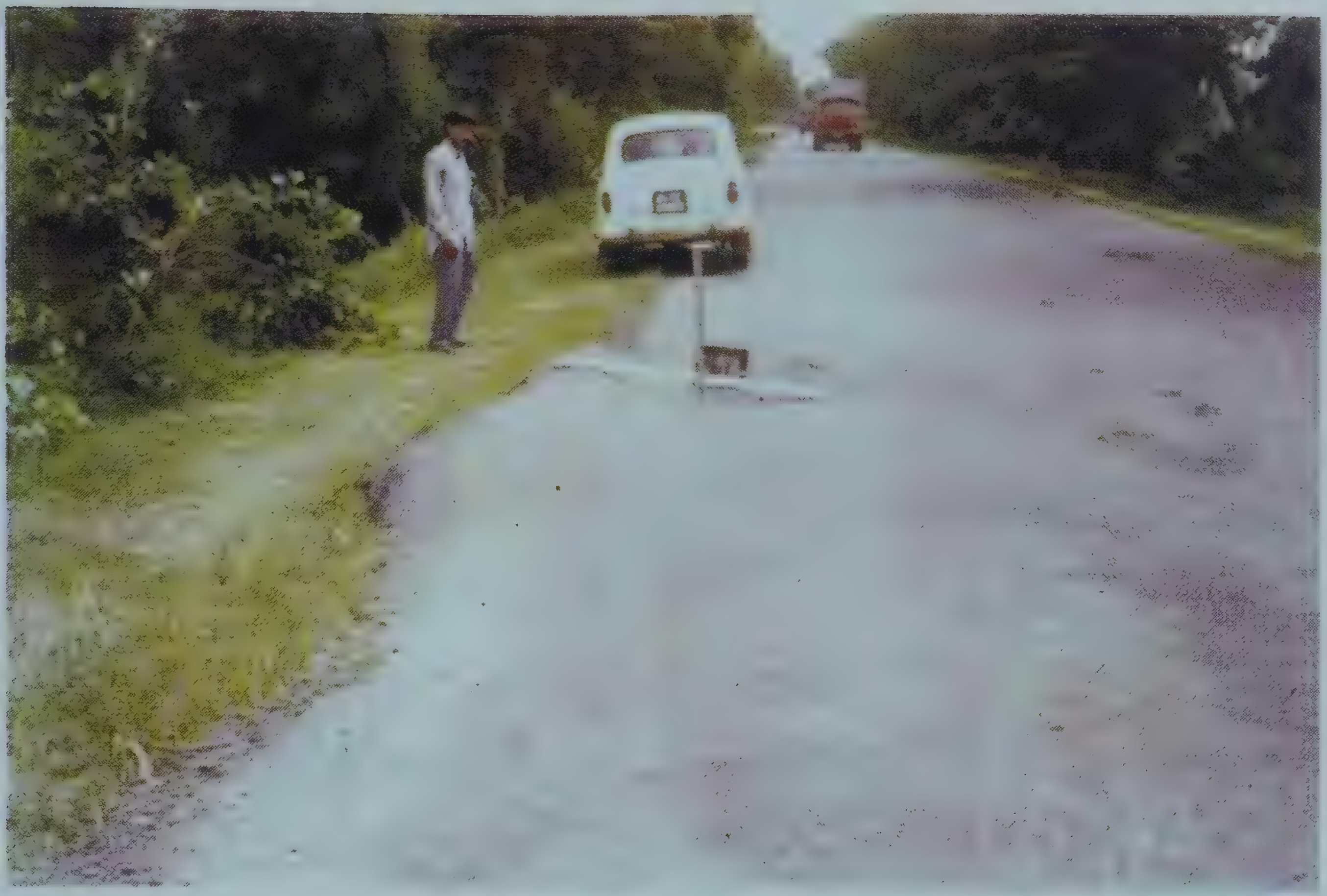


Fig. 9.15. Shoving

Causes

Shoving can be caused by:

1. Lack of stability in the mix (excessive binder, high proportion of fines, too soft a binder) in the surface or base course.
2. Lack of bond between a bituminous surface and the underlying layer.
3. Heavy traffic movement of a start and stop type or involving negotiation of curves and gradients.
4. Use of non-volatile oil on roller wheels.

Treatment

Details have been have been provided in para 8.2.4 for 'Preparation of Surface'.

9.8.6. Shallow depressions

Symptoms

Shallow depressions are localised low areas of limited size (Fig. 9.16), dipping about 25 mm or more below the desired profile, where water will normally collect. The depressions may or may not be accompanied by cracking if not rectified in time, they may lead to further deteriorations of the surface and cause discomfort to traffic.

Causes

Shallow depressions are caused by the settlement of lower pavement layer due to a pocket of weak or inadequately compacted subgrade or pavement layer

Treatment

Details have been provided in para 8.2.4. for 'Preparation of Surface'.

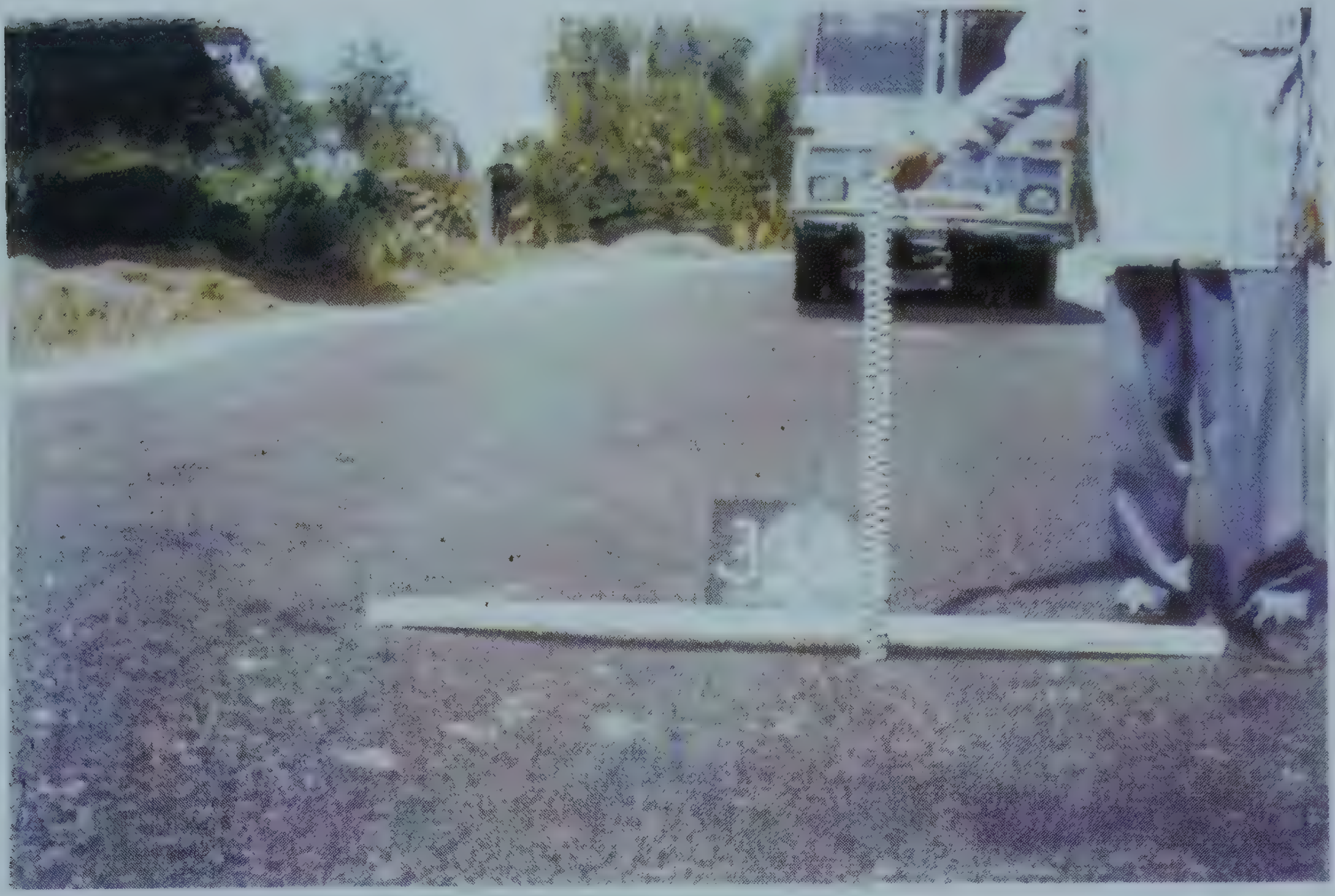


Fig. 9.16. Shallow Depression

9.8.7. Settlement and upheaval

Symptoms

Settlements and upheavals (Fig 9.17) are characterised by large deformations of the pavement. They are extremely dangerous to traffic and cause reduction in speed. They are generally accompanied by extensive cracks in the pavement surface in the affected region.

Causes

The following are the causes for settlements and upheavals (deep shear failure):

1. Inadequate compaction of the fill at locations behind bridge abutments, over utility trenches, etc.
2. Excessive moisture in subgrade and permeable layer of sub-base and base caused by infiltration or capillary action and poor drainage.
3. Inadequate pavement thickness.
4. Frost heave conditions.

Treatment

If settlements and upheavals indicate an inherent weakness in the subgrade, it may be necessary to excavate the defective subgrade and replace it with fresh material under properly controlled conditions. Material having good drainage qualities is preferred. Under-drains may become necessary in locations where lack of drainage has been identified as the cause of failure. Where the cause of deformation is inadequate pavement thickness, then a properly designed pavement should be provided. Frost-affected regions may need thorough investigations and a complete reconstruction of the pavement.

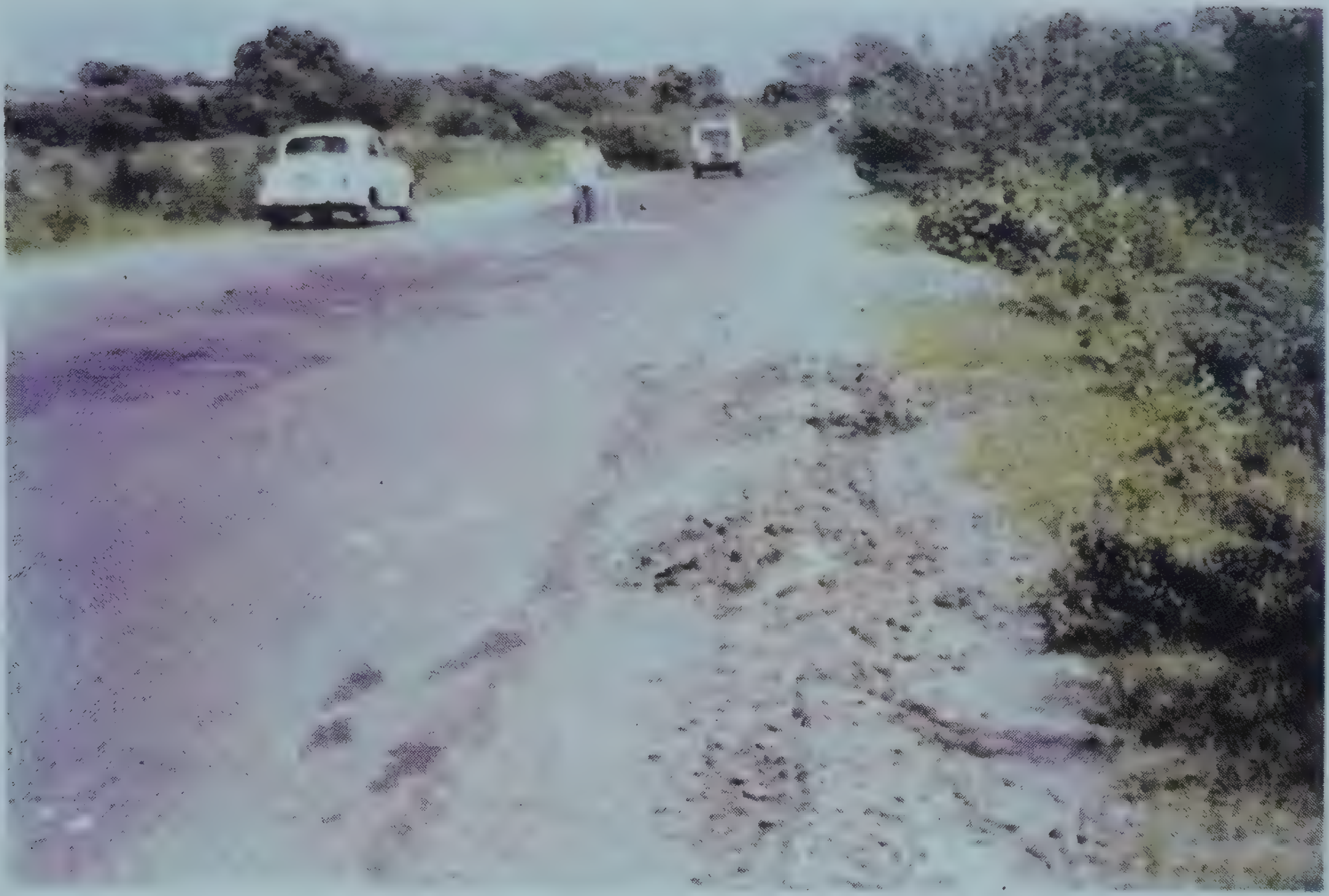


Fig. 9.17. Settlement and Upheaval

9.8.8. Disintegration and its rectification

9.8.8.1. General: There are some defects which, if not rectified immediately, result in the disintegration of the pavement into small, loose fragments. Disintegration, if not arrested in the early stages, may necessitate complete rebuilding of the pavement.

9.8.8.2. Stripping

Symptoms

This defect is characterised by the separation of bitumen adhering to the surfaces of the aggregate particles (Fig 9.18), in the presence of moisture. This may lead to loss of strength and materials from the surface.

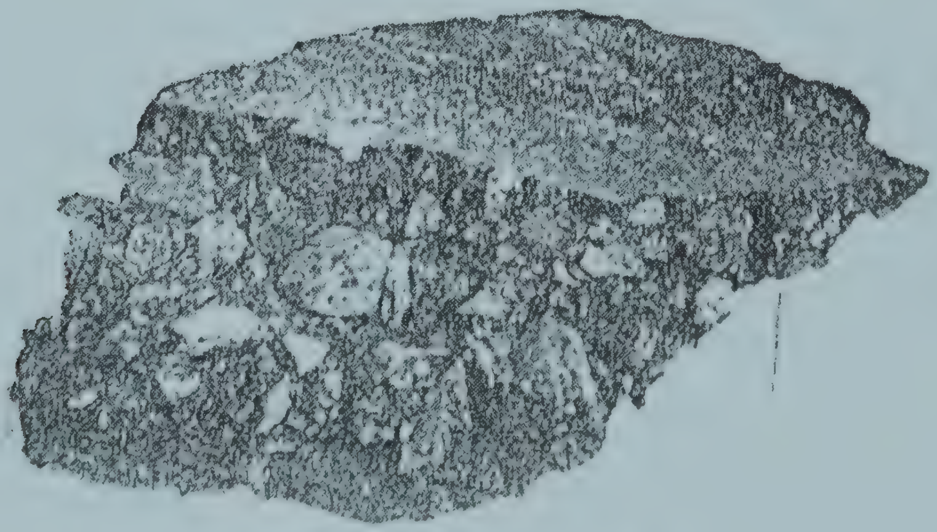


Fig. 9.18. Stripping

Causes

Stripping may be caused by the following:

1. Use of hydrophilic aggregates.
2. Inadequate mix composition.
3. Continuous contact of water with the coated aggregate.
4. Initial over-heating of the binder or the aggregate or both.
5. Peseence of dust or moisture on aggregate when it comes in contact with the bitumen.
6. In the case of surface dressing, poor bond with the surface existing below, delay in spreading the cover aggregate over the sprayed bitumen or insufficient compaction.
7. occurrence of rain or dust storm immediately after the construction.
8. Opening the road to fast traffic before the binder has set.
9. Concentration of soil salt in rain water in contact with the coated aggregates.
10. Use of improper grade of bitumen.
11. Ageing of the bitumen, leading to the brittleness of the binder film.

Treatment

In the case of surface dressing, hot coarse sand heated to at least 150°C and spread over the affected areas, may be used to replace the lost aggregates After spreading, it should be rolled immediately so that it will be seated into the bitumen If aggregates are only partially whipped off, a liquid seal may be the solution.

In other cases, the existing bituminous mix should be removed and a fresh one laid. As a precautionary measure, a suitable anti-stripping agent should be added to the bitumen at the time of construction.

9.8.8.3. Loss of aggregate

Symptoms

Loss of aggregate occurs in surfaces (Fig.9.19) which have been provided with surface dressing. The surface presents a rough appearance, with some portions having aggregates intact and others where aggregates have been lost.

Causes

The loss of aggregates can occur due to the following causes:

1. Ageing and hardening (oxidation) of the of the binder whereby it's adhesive property is lost.
2. Stripping of binder from aggregates due to cold or wet weather before, during or soon after surface dressing.
3. Wet or dusty aggregates to which the binder has not adhered.
4. Insufficient binder for the size of the aggregate used or for the existing absorptive surface.
5. Aggregate having no affinity to the binder.
6. Insufficient rolling before opening to traffic.
7. Fast traffic over new work whipping off the aggregates.
8. Cold-spraying of bitumen or delaying the spreading of aggregates over sprayed bitumen

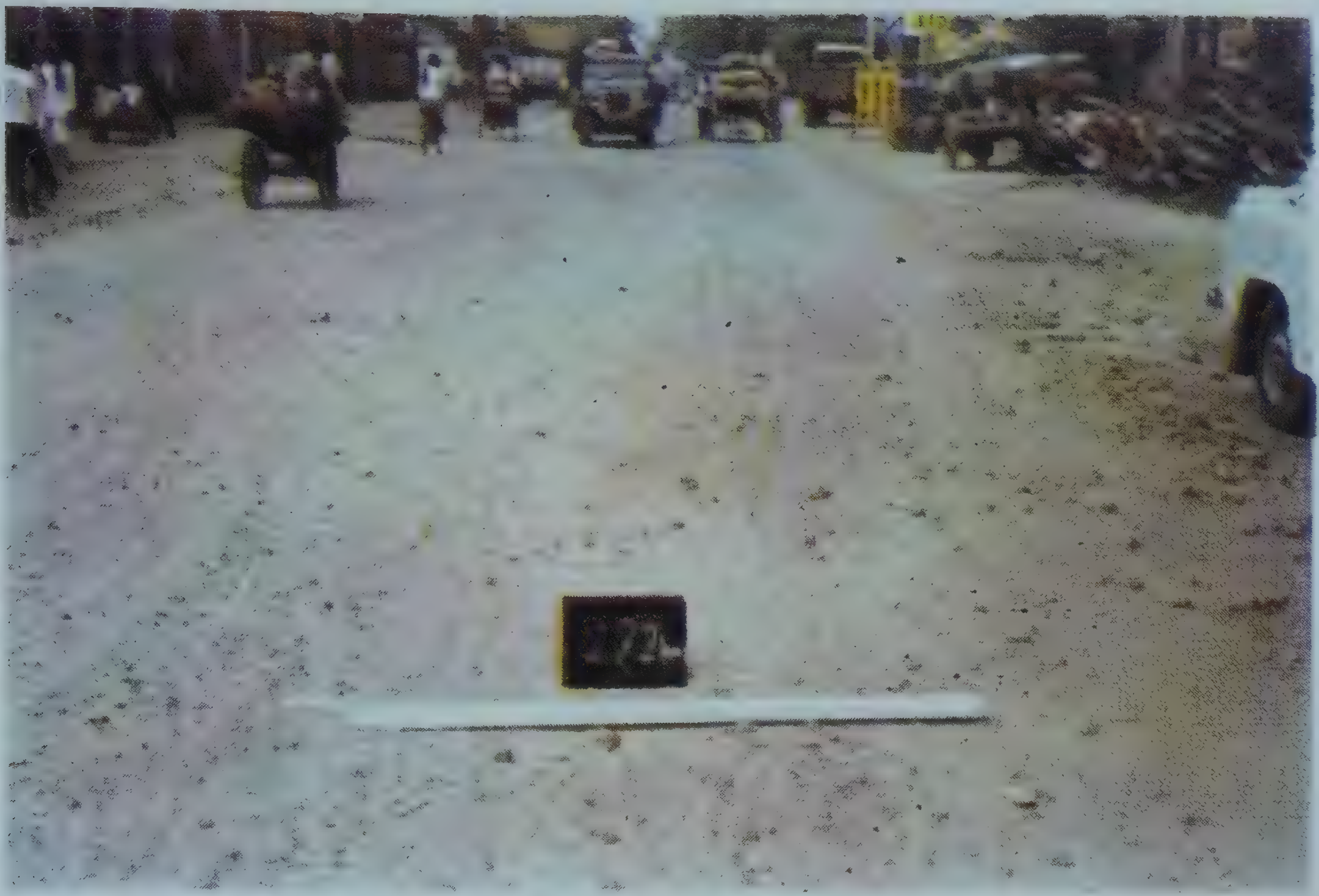


Fig. 9.19. Loss of Aggregate

Treatment

If the loss of aggregates is due to ageing and hardening of the binder, the condition may be rectified by applying a liquid seal, fog or slurry seal.

If the loss of aggregates has occurred over large isolated areas, the best thing to do would be to provide another surface dressing layer, after carefully cleaning the surface.

If the loss of aggregates has taken place in small isolated patches, a liquid seal would be sufficient.

9.8.8.4. Ravelling

Symptoms

Ravelling is generally associate with premixed bituminous layers. It is characterised by the progressive disintegration of the surface (Fig. 9.20.) due to the failure of the binder to hold the materials together. The ravelling process generally starts from the surface downwards or form edge inward. It usually begins with the loss of fine aggregates leaving behind pock marks on the surface and exposed larger aggregate. When larger particles brake free, the surface appears eroded.

Causes

Ravelling is due to one or more of the following reasons:

1. Inadequate compaction during construction.
2. Construction during cold weather resulting in non-uniform binder film.
3. Use of inferior quality aggregate resulting in fracture, crushing and opening of new faces.
4. Insufficient binder in the mix
5. Ageing of binder leading to brittle fracture and disintegration of pavement.

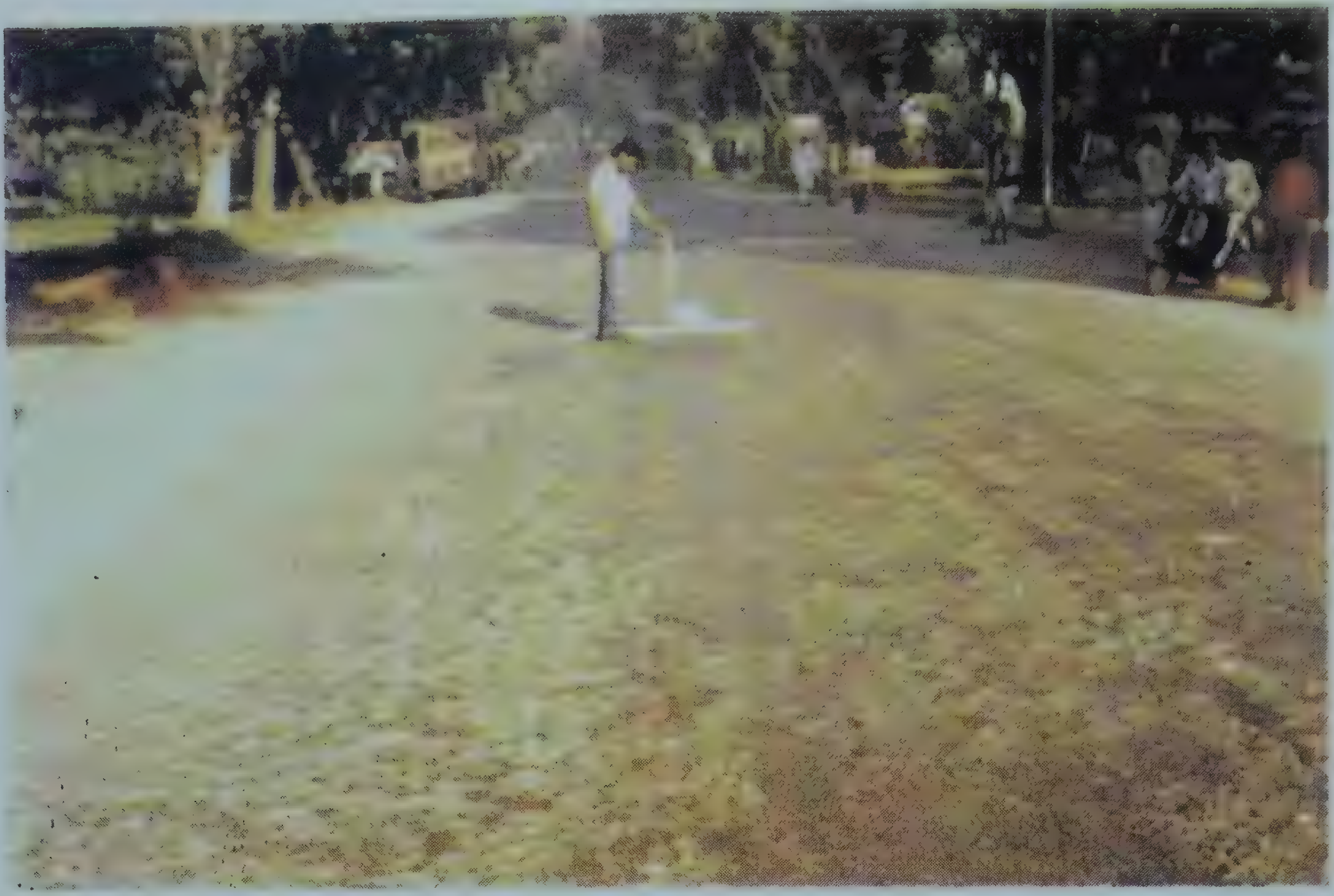


Fig. 9.20. Ravelling

6. Excessively open graded mix.
7. Poor workability in the original mix.
8. Over-heating of mix or the binder.
9. Improper coating of aggregates by binder.

Treatment

A ravelled surface is corrected by adding more binder, the rate of application depending upon the condition of the existing surface and the degree of hardening which has occurred in the binder. If the ravelling has not developed too far, the condition may be corrected by a simple application of a cutback bitumen covered with coarse sand, or a slurry seal can be applied. Where the ravelling had reached an advanced stage, double surface dressing, or an overlay are the preferred options for extending the life of the pavement.

9.8.8.5. Potholes

Symptoms

Potholes are bowl-shaped holes (Fig9.21) of varying sizes in a surface layer or extending into the base layer, caused by the localised disintegration of the usually thin bituminous surfacing material. Hardening of the bitumen, and localised cracking permits the ingress or water, and the action of traffic picks out the surface aggregate in the localised areas affected.

Causes

1. The most common cause of pothole formation is the ingress of water into the pavement through the surface course. This can happen if the surfacing is open-textured and lacks proper camber. Water can enter the pavement also through the cracks in the bituminous surface. Saturated pores and cracks in the surfacing are subjected to high instantaneous pore water pressures under the weight of the wheels of passing traffic. These pressures lead to gradual

disintegration of the surfacing material and the aggregate begins to pick out under traffic. If not attended to promptly, the aggregates in the surface get progressively loosened and the affected area increases rapidly in size and depth and may progress down into the base course. This is aggravated by use of plastic filler in granular layers.

2. Lack of proper bond between the bituminous surfacing and an underlying granular base course may also cause potholes. The bond is usually provided by a prime or tack coat, and any localised inadequacies in these applications in the original construction may cause the top surface to disintegate forming the start of a pothole.
3. Insufficient bitumen content in localised areas of the surfacing layer can cause pot-holes where the bitumen is insufficient to hold the stone under traffic.
4. Too thin a bituminous surface, which is unable to withstand the haevy traffic, can also cause potholes, when associated with improper or inadequate with camber.
5. Pot-holes in dense graded mixtures are usually the result of inadequate mix design, where there is insufficient binder to hold the material together. Voids filled with bitumen is too low.

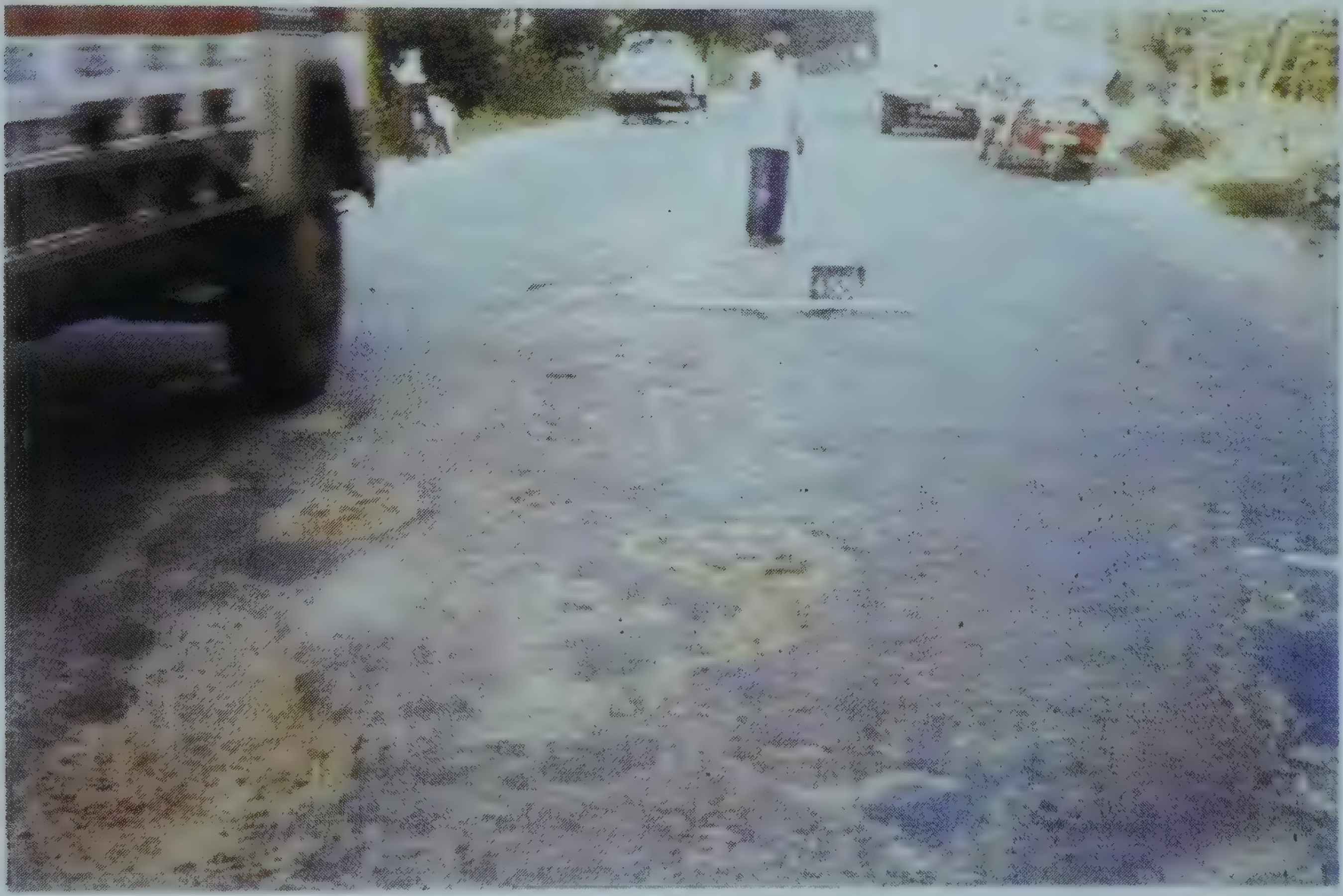


Fig. 9.21. Patholes

Treatment

Details have been given in para 8.2.4. for preparation of Surface;

9.8.8.6. Edge failure

Symptoms

A Common defect in bituminous surfaced roads is edge cracking, and spalling. The edge of the bituminous surface gets broken in an irregular way (9.22), and if corrective measures are not taken promptly the failure is progressive and results in a significant loss in carriageway width.

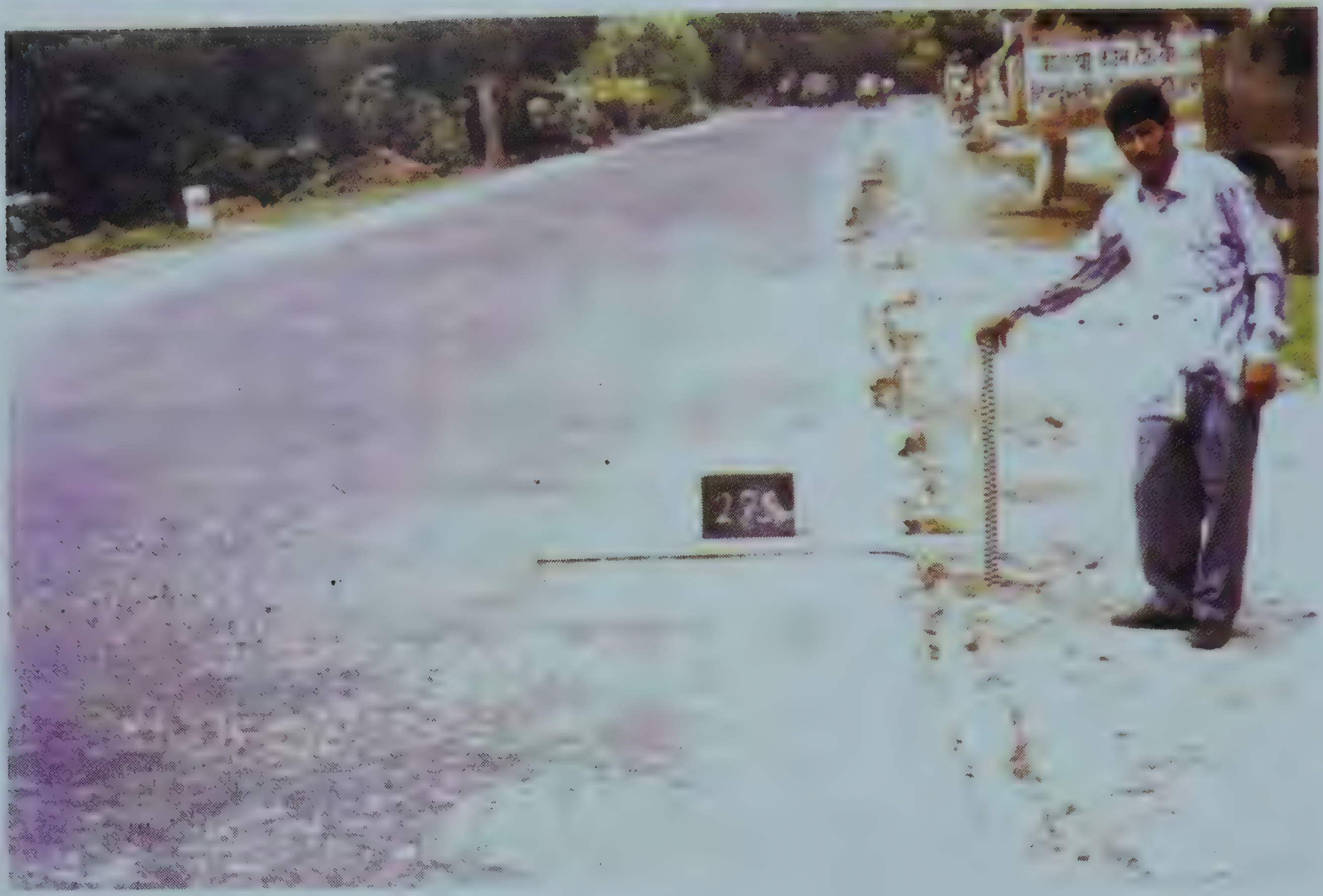


Fig. 9.22. Edge Failure

Causes

The following are the causes for edge breaking:

The single most common cause of edge failure is bad drainage at the carriageway edge, where the shoulder has become raised by dust and dirt thrown up by traffic. The raised shoulder prevents runoff into the side drain, and water stagnates at the junction of the carriageway and shoulder. This penetrates the road base which is thereby weakened and failure of the structure follows rapidly.

Other reasons for failure are: -

1. Infiltration of water which softens the foundation layers causing the pavement edges to break.
2. Worn out shoulders resulting in insufficient side support to the pavement.
3. Inadequate strength at the edge of the pavement due to inadequate compaction.
4. Lower layer of pavement not being wider than upper layer.

Treatment

The shoulder, pavement material and any affected subgrade material in the affected area should be entirely removed to a regular section with vertical sides. The pavement and the shoulders should be rebuilt simultaneously with thorough compaction. A bituminous surface similar to that used before should be laid. The shoulder should have adequate slope to drain away rainwater. A slope at least 2 per cent steeper than the camber of the bituminous surface is generally necessary for earthen shoulders.

Prevention

The old adage "prevention is better than cure" is never more true than in this type of failure. In order to prevent the edges from getting broken again, the maintenance operations should include periodic inspection of the shoulder condition, which shoulder graded off to the correct level and profile with adequate compaction. In sandy areas, where the shoulder is likely to be eroded by wind and rain, it may be necessary to have brick paving at least for some width to protect the edges. Surface and subsurface drainage, wherever deficient should be improved. Where the longitudinal gradient is greater than 5 per cent, it may be necessary to surface the shoulder in some way to prevent erosion. Single or double surface dressing is often the most economic treatment in this instance.

9.9. Specialist Repairs

Specialist repairs include repairs of localised areas of damage to materials for which repairs using normal hot-mix patching materials are inappropriate. Such specialist repairs will include repairs to mastic asphalt and stone mastic asphalt.

In such cases, pot-hole and patch repairs should be carried out as already described, except that the construction to the mastic asphalt, stone mastic asphalt or other specialist material layer should be carried out in accordance with the provisions appropriate to these materials (see Chapters 4 and 8).

9.10 Ministry's norms for Road Maintenance in India

The ministry of Road Transport and Highways has been recommending from time to time, the maintenance norms for different categories of roads in India. The salient features of the latest recommendations (October, 2000) are as under:

9.10.1. Maintenance activities : The maintenance activities have been divided into the following heads :

(a) **Ordinary Repairs:** These include routine maintenance such as crack sealing, filling of potholes, depressions and ruts in a bituminous surfacing, repairing of shoulders etc,. among a large number of other routine maintenance items.

(b) **Periodic Renewals:** These include provision of renewal coat to the wearing surface at a predetermined frequency, with a view to safeguard the pavement crust and also improve the riding quality. These renewals are envisaged to be carried out with mechanised equipment and in a continuous stretch of at least 5 to 10 km.

(c) **Special Repairs:** These include works of original nature such as minor improvement to curves, visibility, repairs to culverts, bridges etc.

(d) **Emergency Repairs:** These include immediate repairs to roads affected by heavy rains/floods, cyclones, land-slides etc,. needed to restore traffic.

9.10.2. Price zones: For purposes of working out the relate maintenance costs, six price zones (I to VI) have been arrived at in the country on the basis of cost of stone stone aggregates. For roads in hilly areas, where the cost of material and labour is more than in other regions, one more zone (VIO A) has been added. The cost of stone ships in Rs. per cum vary from Rs. 280 - 350 in Zone 1 to Rs. 740-860 in Zone VI A.

9.10.3. Traffic : From the view point of traffic, in terms of the number of commercial vehicles per day, five categories have been arrived at : (i) less than 150 (ii)150-450 and (iii) 450-1500.

9.10.4. Road categories: separate sets of norms have been recommended for National /state Highways; for MDR/ODR/VR; for Urban Roads and for Hill Roads.

For purposes of illustration, a summary of total Maintenance and repairs cots per year in Rs. Pre Km Double lane (7m) with 1.5 m paved shoulder of NH/SH is given in Table 9.3

Table 9.3 Zonewise summary of Total Costs per Year in Rs. per Km Double Lane (7.0 m) with 1.5 m Paved shoulder of NH\SH with reference to Traffic & terrain

Category	Traffic in CVD				
	Less than 450	450-1500	1500-4500	More than 4500	More than 4500
	B.T. Surface				Cement Concrete
Zone- 1					
Normal	328724	406429	455807	621503	138165
Urban	476673	529271	588326	793250	186395
Zone- II					
Normal	337750	418039	468363	640415	148110
Urban	489565	543270	603362	816128	196340
Zone-III					
Normal	344567	427218	478575	655801	157665
Urban	500249	554332	615555	834685	205895
Zone-IV					
Normal	353974	434688	493886	679047	167220
Urban	515951	563127	633946	862858	215450
Zone-V					
Normal	362021	452518	506876	698719	170405
Urban	529465	584931	649518	886661	218635
Hills	689663	754145	842058	927986	-
Zone-VI					
Normal	369591	463545	519402	717647	176775
Urban	542424	598232	664509	909535	225005
Hills	707634	772550	862628	952619	-
Zone-VI A					
Hills	735087	801916	890511	988264	-

[1] New Specification: Clause 522 of MoRT&H Specifications

[2] New Specification: Clause 522 of MoRT&H Specifications

CHAPTER 10

CONSTRUCTION SUPERVISON AND QUALITY CONTROL

10.1. Quality control

10.1.1. Definition of quality: Quality might be defined as 'the totality of features and characteristics of a product or service that imparts the ability to satisfy specific needs for the end product'. In the case of road construction, the requirement to achieve "quality" will cover all aspects of the aspects of the construction and performance in service, including materials quality, both before and after and after incorporation in the works, dimensional control, level of service or performance and durability.

10.1.2. Need for quality control: In order to ensure that the end product will be endowed with the required qualities, the proper supervision of all aspects of the construction process is essential. Since, for most construction works, the long-term durability and performance of the works cannot be apparent or measurable during or immediately after the construction period, the quality control process must be related to the achievement of certain parameters, which are immediately measurable, and in this achievement the work is deemed to provide the finished product with the ability to meet the required long term aims of performance and durability. The setting of the standards which are applied to the construction both at design and construction stages are largely empirical, and based on experience. Thus in designing and constructing a pavement structure, we have to assume that because a particular construction in similar conditions was previously successful, it should work again. This is unfortunately not always the case.

10.1.3. Quality control in road construction : In broad terms, It is generally accepted that the quality of road construction work can be measured by testing the finished product, and most acceptance tests are based on this premise, However, for those actively engaged in the construction process, control must be exerted over procurement of materials and their processing if the required finished quality is to be achieved. Thus, quality control should mean significantly different things to different sections of the road industry.

Quality control and specifications in road construction must cover workmanship and materials. The two most important means of specifying a finished product are: (1) by method, and (2) by end result. The more reliable is the latter, but there are circumstances where this cannot be applied and a method specification must be used. An example is in the production of concrete. It is usual to require an end product (a set strength for the concrete, that the designer can rely on in his design). While it is possible to test the end product by cutting and testing cores, it is more usual to control the production by method (gauging the aggregates, cement, and controlling the amount of water added, and the mixing time). Check testing is carried out during production, with such tests as slump tests, and cubes are cast with the finished product, which are crushed after curing to ensure compliance as a cheek. However, control of production is largely by method.

The standards to be achieved in the construction of major roads in India are incorporated in the Ministry or Road Transport and highways Specifications for Road and Bridge Works: crrent revision. This is principally an end result specification, although in a few areas, certain limitations are placed on equipment and processes.

Previous chapters of this Manual addressed different aspects of the practicalities of construction This Chapter therefore addresses construction supervision from the point of view of those charged with the responsibility of monitoring construction and accepting the completed work.

10.1.4. Quality control in India

10.1.4.1. Present practice: Under the systems presently practised in India, quality control work is generally carried out under a 2-tier system or even a 3-tier system depending on the total workload of a particular department at a particular time.

Primary or Division Level Control

Working on the principle that the unit responsible for construction should also be responsible for its quality, the primary level of control and check testing is entrusted with the Engineer-in Charge of the work and his staff. Generally it will be the Executive Engineer under whose jurisdiction the work falls.

The primary level check consists of:

(i) carrying out at least the minimum number of mandatory tests in respect of all materials and processes,

(ii) ensuring that only materials duly approved by a competent authority and from approved source (borrow area, quarry, etc.) and those manufactured materials having an appropriate certificate of quality from the manufacturer have been incorporated into the works; and

(iii) the equipment used is as per specification, and is in good working order and processes followed are as specified.

Supervisory or Circle level Control

The second level of quality control is at the supervisory level under the control of Superintending Engineer-in Charge of the circle, and the quality control team may be headed by an Executive Engineer-in-Charge of the regional laboratory in the circle, or by his staff.

The work of the team includes:

1. Carrying out random checking of the quality of materials including verification of the use of approved products or materials from approved sources;
2. Verification that records of field tests are being kept properly; and
3. carrying out important tests (in the regional laboratory) if equipment and arrangements for such tests are not available in the field laboratory.

Third Level (Optional) Quality Control

The third level of quality control, where considered necessary, may be carried out by the Core Cell under the charge of the chief Engineer of the project.

The Core Cell may monitor the effectiveness of the control being exercised by the Circle and Division level units and carry out such tests as it deems as it deems necessary.

The Core Cell also acts as and apex body in respect of all quality control problems and may lay down norms for modification/updating of control and test procedures as well as changes in Specifications for future works.

10.1.4.2. Recommended practice for large projects: Given india's large road construction: reconstruction and rehabilitation needs, emphasis will inevitably move more and more to construction by contractors supervised by Consultants. In this context, Quality Control rests with the Resident Engineer and his staff (particularly a qualified Materials Engineer) and control testing is centred on a Site Laboratory. The Site laboratory must be equipped to deal with all testing in an expeditious manner to avoid delays to the progress of the work and claims by the Contractor. On such projects, because of time constraints, it is not possible for samples to be sent away for testing elsewhere except in the special case of non-standard, non-urgent tests, if any such are required. The personnel appointed to carry out the field and laboratory testing will generally be qualified and experienced specialist technicians and engineers, and the site laboratory equipped to perform all but the very specialised tests which are required very occasionally.

10.1.4.3. Systems or quality control: The assessment of completed construction work, with a view to its acceptance, as conforming to the required standards, must be undertaken in a systematic manner. The completed work is generally tested for the following and only when the completed work is found satisfactory will the next phase of work be allowed:

- Visual inspection
- line and level
- materials testing

It is strongly recommended that the authority responsible for acceptance of work should institute a system for written certification, so that, for every item submitted for acceptance, a positive acceptance certificate covering all three categories should be provided before acceptance is given.

10.2. Line And Level

10.2.1. Survey reference control: In bituminous pavement work, great importance must be attached to the achievement of accuracy of line and level. In order to be able to construct the works within the required tolerances, it is essential that the setting out of the works, and all line and level controls intended for use during construction of the works are established to the highest standards of accuracy and reliability. Without well thought out construction controls there will be no realistic chance of achieving the high standards of line and level, of the finished works, required by the Specifications.

No survey work or construction work should be undertaken until a reliable system of permanent survey references and benchmarks have been established Clearly, the survey reference must be accurately related to the system employed to collect the ground data used in the preparation of the design. A system of robustly-constructed inter-visible references (at a spacing of not more than, say, 250 metres) should be established, incorporating whenever possible any previously established beacons, located in places where they are unlikely to be disturbed by subsequent construction operations.

10.2.2. Horizontal alignment: The horizontal alignment must be established repeatedly as construction progresses, using theodolites, or total stations for preference because their use offers fewer opportunities for error. Such setting out must always be carried out by direct reference to the main established survey beacons.

10.2.3 Level control: It is usual to relate level controls to defined cross-sections, and so the establishment of hose cross-sections, accurately on chainage, at the required intervals and at right angles to the road centre-line, is essential. The type of control to be use will vary according to the construction process, but whether the control consists of batter-boards, or control-wires or any other type,. the requirement for the accurate transfer of level from primary bench-marks remains.

10.2.4. Assessment of line and level: while it is clearly necessary for the work under consideration to be completed before it can be assessed, there are a number of things that can be done, in advance, that can make the assessor's tasks easier and may also be of benefit to those responsible for the construction.

As a rule, it is important than the assessors should be using the same system of survey reference to assess the work as were used to construct it. To use a different reference system is clearly undesirable.

This in turn implies that the assessors should satisfy themselves that the reference system is accurate. Checks should be carried out, by the assessors, on the reference system and any errors reported to the construction team.

When measurement are made of line and level, they should be compared with the specified standards, taking into consideration the allowable tolerances.

10.25. Construction tolerances : The accuracy required by the Ministry's Specifications for construction of horizontal alignment of the finished pavement layers is ± 10 mm. The permitted deviations from the longitudinal and cross profile for the various layers of the road are given in Table 10.1.

Table 10.1 Tolerances in Surface Levels

1.	Subgrade	+20 mm
		-25 mm
2.	Sub-base	
	a. Flexible pavement	+10 mm
	b. Concrete pavement	-20 mm
	(Dry lean concrete or Rolled Concrete)	+6 mm
		-10 mm
3.	Base-course for flexible pavement	
	a. Bituminous course	+6 mm
	b. other than bituminous	-6 mm
	(i) Machine laid	+10 mm
		-10 mm
	(ii) Manually laid	+15 mm
		-15 mm
4.	Wearing course for flexible pavement	
	a. Machine laid	+6 mm
	b. Manually laid	-6 mm
		+10 mm
		-10 mm
5.	Cement concrete pavement	+5 mm
		-6 mm*

This may not exceed -8 mm at 0 - 30 cm from the edges.

10.3. Trial sections (Laying Trials)

For all manor bituminous construction works, it is of utmost importance that suitable trial sections be laid (preferably away from the carriageway to be constructed) before the actual commencement of laying on the road. This procedure should be mandatory making it possible for the Engineer-in Charge to satisfy himself as to the capability of the Contractor to carryout the construction work according to specified requirements of grade, level, thickness, compacted density, surface regularity and other related design parameters. Normally, the length of such full-scale trial sections, should not be less than 30 m. More than one trial section may be needed before the Contractor can accomplish, to the satisfaction of Engineer-in-Charge, that all the specified requirements are indeed met with In the process, an appropriate job-mix formula can be more effectively established. This is of special importance for projects involving the use of emerging materials such as polymer modified bitumen/fibres, etc.

It is essential that the area selected for the laying trial, has the same characteristics as to strength and surface regularity as the surface to be laid on the road. For this reason the Contractor will usually want to use a section of the prepared road for the laying of trials. If this is permitted by the Engineer, it should clearly be stated in writing that as a condition of approval for such a laying trial it is entirely at the Contractor's risk, and if unsuccessful, must be raked up, surface made good and recompacted, and surfacing re-laid.

The surface regularity of the finished surface must also be tested and must conform to standards given in table 10.2.

Table 10.2. maximum permitted number of Surface Irregularities

	Surface of carriageways and paved shoulders				Surfaces of lay-bys, service areas and all bituminous base courses			
Irregularity	4 mm		7 mm		4 mm		7 mm	
Length (m)	300	75	300	75	300	75	300	75
National Highways/Expressways*	20	9	2	1	40	18	4	2
Roads of lower category*	40	18	4	2	60	27	6	3

*Category of each section of road as described in the Contract.

10.4 . Visual Inspection

The distinction is drawn here between inspection of works in progress, and the inspection of completed works with a view to their acceptance. It is not in any way implied that regular inspection of the works while in progress is not a vital function, indeed there are elements of the construction process that are directly addressed by the Specifications and, as such must be adhered to. However, while other elements of the construction process may be inspected, they are not necessarily always relevant to the final acceptance ot the finished product. Visual inspection to the finished product at every stage of construction is indispensable (e.g. inspections of completed subgrade, for instance, is every bit as important as inspection of completed wearing-course).

Visual inspection is not necessarily carried out with any specific set of criteria in mind. It is however essential because, whatever the frequency of survey checks, and material tests, these cannot realistically be taken as guaranteeing that all locations, are without fault. Visual inspection will often serve to detect suspect areas of work that have not been detected by other means.

10.5. Sampling

10.5.1. Sampling of bituminous binders

10.5.1.1. Manufacturer's certificate: It is most important to firstly obtain a manufacture's certificate for bulk bitumen supplied from the Contractor's supplier. The source should be specifically approved by extensive testing of a sample before delivery to site.

Once the source is approved, the regular supply of bitumen must be tested on site, on a load by load by load basis, at least for penetration, before the tanker is permitted to discharge.

The bituminous binder to be subjected to tests must be of a representative nature.

Test results of a material sample, which is not representative of the total material quantity, may give wrong signals for action or treatment and design based on the same may not result in quality material.

10.5.1.2. Sampling : if the supply consignment is large, truly representative samples should be obtained from different locations and tested to see the extent of uniformity in the material.

If the average quality of the material is to be checked, the samples so obtained from different parts may be mixed thoroughly and then the average sample subjected to testing.

10.5.1.3. When to take samples: All samples should be obtained before the incoming vehicles containing the material are unloaded into storage or sent out for use on current work.

10.5.1.4. Solid state sampling : For obtaining samples from materials in a solid state, a hammer and a scoop will be required in addition to a metal container with a lid in which the material will be collected.

If the material is in a drum in solid or semi-solid state, the drum or the barrel should be opened at one end, the top layer of the binder should be removed at least up to 75 mm thickness and then the required quantity of sample taken out and placed in a metal can and covered.

If there are a large number of drums forming a consignment, useful rule-of-thumb is to obtain a minimum number of samples equal to about the cube root of the total number of drums.

10.5.1.5. Liquid sampling : For the collection of liquid samples, sampling tubes and/or cans of suitable material with caps are required (Fig. 10.1.)

Generally, for cutbacks and liquid asphalt, metal cans (preferably of oblong shape) with screwable metal caps are used so that the volatiles are not allowed to escape.

Ordinary wide-mouthed round metal cans with caps or friction taps can be used for collection of samples of bitumen.

Collection vessels of different shapes and materials help in ready recognition of the type of material they contain.

While metal caps and corks may be used for capping the collection vessels, stoppers made of rubber or similar material, which chemically react with petroleum products, should not be used.

10.5.1.6. Sampling tube: If the material is hot and is in a liquid or viscous liquid state, say to be obtained from a tank truck, the sample should be obtained with the help of an open or closable sampling tube from a top opening in the tank.

The open- type sampling tube is used for sufficiently viscous binders, which may not drip, while the closable tubes are used for binders in a more liquid state.

For taking the sample, the tubes are pushed into the material vertically from the top, keeping the bottom valve open. In this way material from the entire cross-section of the tank enters the tube. The bottom valve is closed when the tube touches the bed of the tank after which the material is drawn out.

10.5.1.7. Sampling from valves: When the material is hot and in a liquid state cable of flowing through the pipe of the tank, a sample can be collected in a metal can either from the sampling valves on the tank/ truck or through the discharge valve.

While operating the sampling valve of a tank truck, first check that the valve is closed and then take out the metal screw cap at the end of the discharge spout.

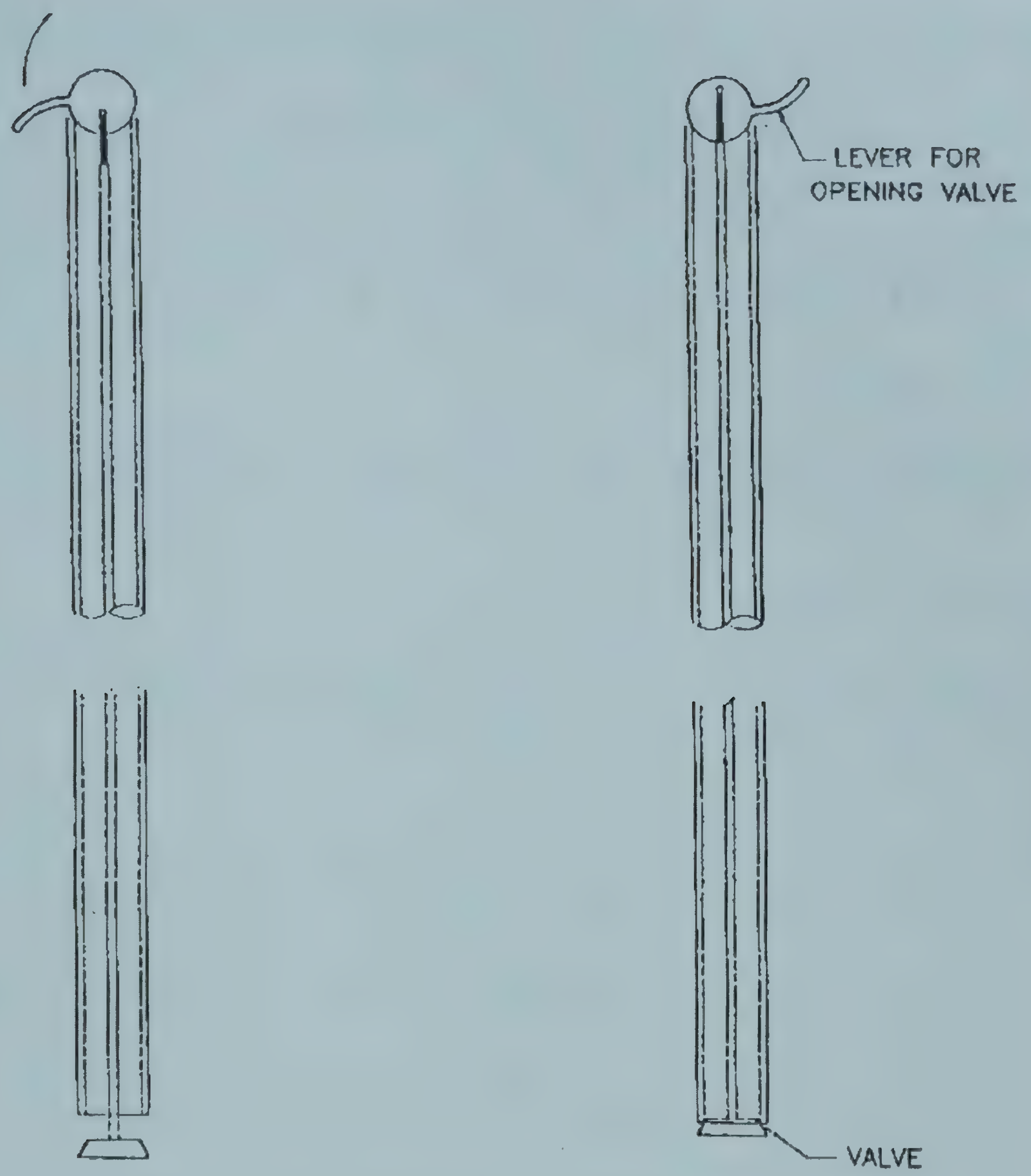


Fig. 10.1. Sampling Tubes for Bituminous Binders

Then check that the spout and the channel are clear of any obstruction or clogging by solidified bitumen.

The valve should then be opened very slowly and a litre or so of the first material taken out in a separate vessel to smoothen the flow and clean the flow-line.

The valve should be closed again.

The sample collector should then be placed just below the spout and, very slowly and carefully, the valve should be opened again so that the material does not gush out but falls in a slow and steady stream.

When the collection vessel has a 10 mm or 20 mm gap on the top, the valve may be closed and the remaining part of the material in the spout and the channel allowed to be collected in the vessel without removing it.

The spout and the outside of the collecting vessel should then be wiped out with a piece of clean cloth and the cap on the collecting vessel fitted loosely until the material cools down to surrounding temperature. Immediately on cooling, the cap should be fitted firmly so that the sample is not contaminated by dirt or any other foreign material. If necessary, the cap can now be sealed.

10.5.1.8. Record labels : The outside of the collecting vessel for the sample should then be cleaned properly and a label containing information about the sample should be pasted on the wall and the writing protected by covering the label with transparent gummed cellophane or tape.

Information recorded on the label should have at least the following :

(i) Date of collection.

(ii) Sample number.

(iii) Source of supply, (truck number also).

(iv) Type of binder.

(v) Consignment identification etc.

10.5.1.9. Transporting samples : Depending on the distance to be travelled before testing and the mode of transport, the sample may require packaging in a cardboard carton, or wooden case with corrugated (paper, cushion material etc.

10.5.2. Sampling of aggregates

10.5.2.1. Representative samples : Aggregate samples for testing must be of a representative character of the whole lot or consignment of supply. Otherwise the test results will not be indicative of the true condition of the material in stock and the action and design needed for their proper use.

10.5.2.2. Collection of samples

1. When the samples are to be collected while the aggregate is in movement, either on its way to a stock-pile or being loaded or unloaded for storage or from conveyor belt, samples should preferably be taken in a number of small instalments spread over a period of time rather than all at one go from a particular point.

   All these small collections should then be thoroughly mixed and the resulting large sample quartered until samples of a suitable size for each test are obtained.

2. If the sample is obtained from a bin or a stockpile it should be made up of equal quantities of material from holes or openings made into the surface of the stockpile. The material should be obtained from the top, middle and bottom or the stockpile from a number of widely spread points equally distributed on the surface area. (Fig. 10.2).

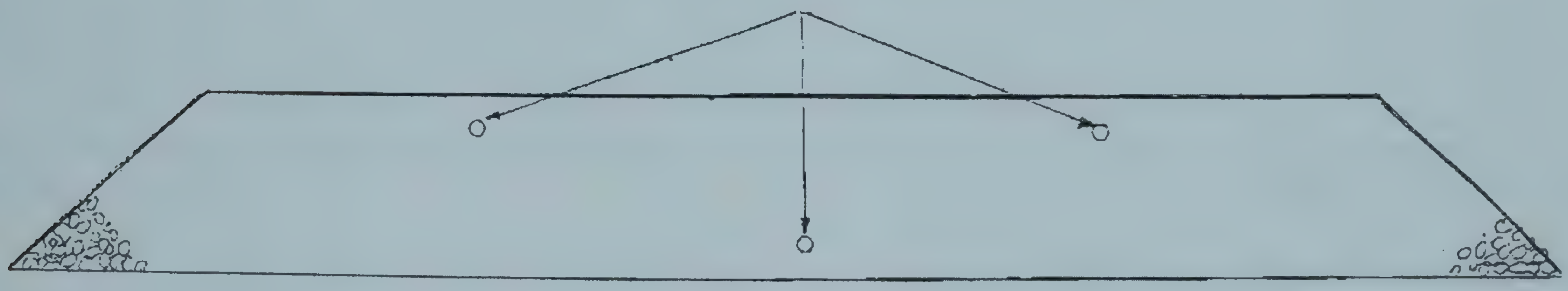


Fig. 10.2. Sampling from Flat Stockpiles

   The sample so collected should then be reduced in size either by quartering or by a sample divider (riffle box). (Fig. 10.3).

3. If the sample cannot be collected at the source or at destination but has to be obtained either from a truck or a railway wagon, it should be obtained from at least six different points at a depth at least 0.3 metre below the surface.

   For this purpose, the top area of the wagon may be divided into six compartments by a median line placed lengthwise and two cross-lines at right angles to it dividing the length into three equal parts. The sample should be collected fror the mid-points of these six areas.

   If the surface area involved is very large, increase the number of equal size compartments.

4. The samples so collected should be thoroughly mixed and then reduced in quantity either by quartering or by use of a sample-divider (riffle box), to obtain sub samples of an appropriate size for each test.

10.5.2.3. Sample divider (or riffle box) : The sample divider is illustrated in Fig 10.3. It is divided into an even number of narrow cells with chutes, which discharge alternatively to the two sides. Aggregate poured in at the top is divided into two portions which are collected in suitably placed boxes. If smaller samples are needed the aggregate in the box is divided again into two empty boxes and this dividing process is repeated with one half until the required size of sample is obtained.

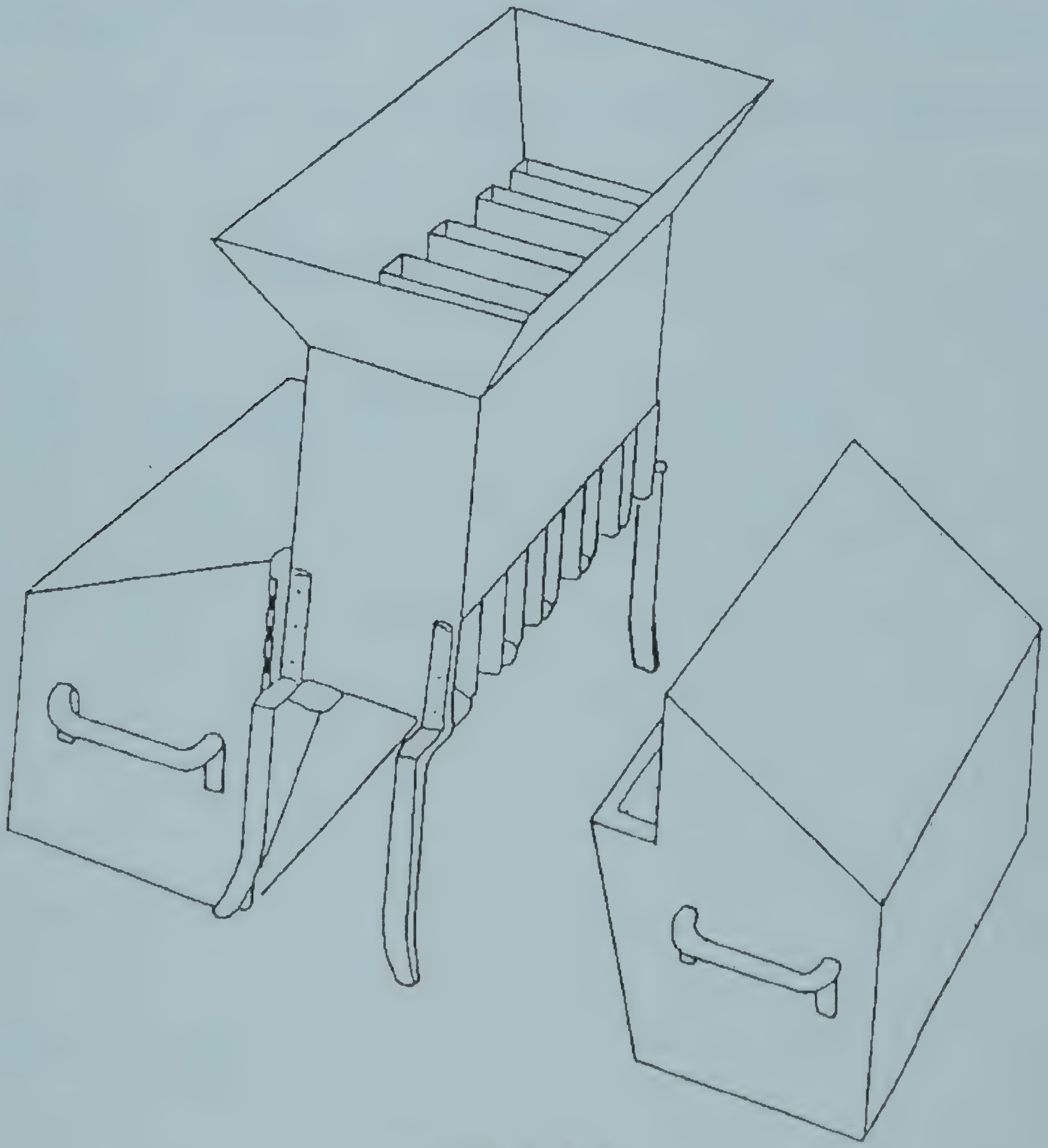
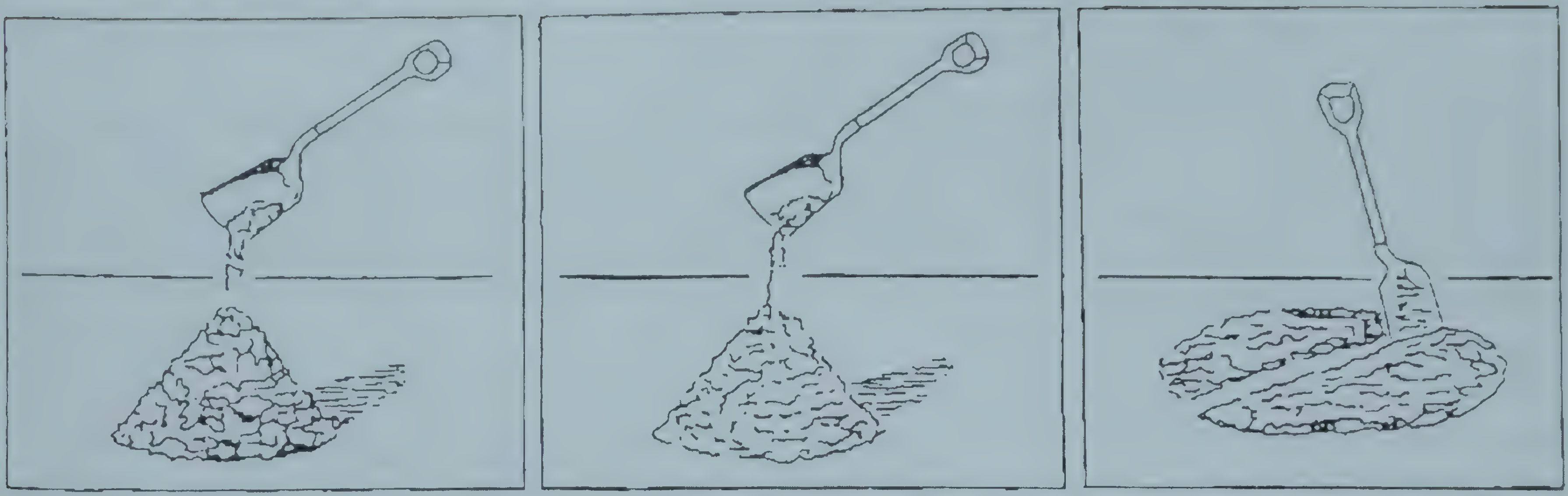


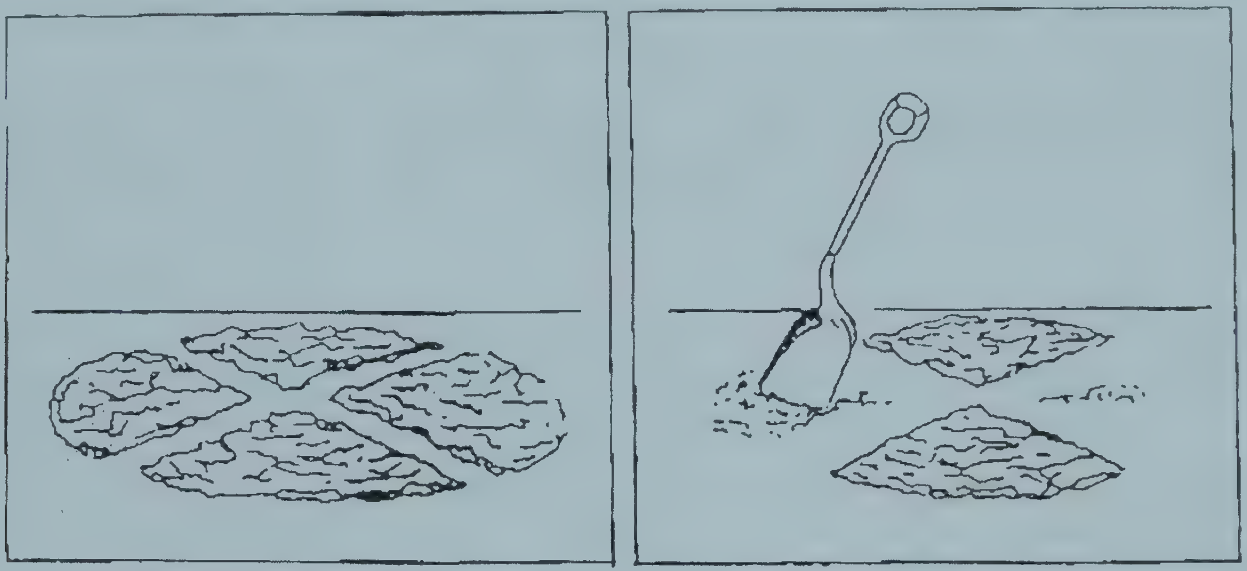
Fig. 10.3. Riffle Box

10.5.2.4. Quartering : A stepwise procedure of "quartering" (shown in Fig. 10.4) is outlined below:

1. The quartering operation can be undertaken either on a plywood board of sufficient area, on a tarpaulin sheet (at least 2 m x 2.5 m in size) or in the absence of any of the two, on a cleanly swept floor.
2. Pour the entire sample material on to the board/tarpaulin or on the cleaned floor.
3. With the help of a square-nosed shovel, mix the material thoroughly up and down at least three times.



1. Cour Smupic on Bald Chan Surface 2. Mix by Farming New Cone 3. Quarter Alley Flattening Cone



4. Sampie Divided into Quarters 5. Retain Opposite Quarters Reject the Other Two Quarters

10.4. Preparation of Sample by Quartering

4. During the last turning, place each shovel of material one above the other forming a conical heap.
5. Then flatten the cone with the backside of the shovel and spread the material to a flat circular shape of equal uniform thickness with a small height.
6. With the help of the shovel, now split the material into four equal quadrants with a clean wide separation line between each quadrant.

   Remove the materials in two opposite quadrants.
7. Mix the material in the remaining quadrants thoroughly and subject the mixed material to the same quartering process again and again till the final desired quantity of sample material is obtained.

While rejecting two quarters of material care should be taken to see that none of this material, even fine dust, mixes with the remaining quarters.

If necessary, the material can be slightly damped so that no fines fly about and the area occupied by the quarters removed can be swept clean.

10.5.3. Sampling of paving mixes

10.5.3.1. Visual Checking and Daily Reporting : It is important to visually check the mix as it is being discharged from the plant into the truck and as it is leaving the plant on the way to the paving site. Whether the temperature of a load of mix is within the proper range can be very quickly and conveniently gauged by visual inspection. If the mix temperature is too high, blue smoke rising from the truckload of the mix is an indicator. If the mix temperature is too low, the mix showing a sluggish appearance as it is deposited in the truck, non-uniform distribution of bitumen and an abnormally high peak in a truckload are often the indicators of under heating. If, however, the mix slumps without a proper peak in the truck, it may be indicative of excessive bitumen or excessive moisture. Even though visual inspection is extremely helpful, it is necessary to measure the temperature of the mix in the truck, using a dial and armoured stem thermometer, at least 500mm long (Fig. 10.5). It is also necessary that the plant operator gives a daily report. A format suggested by the Asphalt Institute of USA as shown in Fig. 10.6 is quite suitable for Indian conditions. The possible causes of mix deficiencies in hot-mix asphalt outlined by the Asphalt Institute of USA are also given in Table 10.3.

Table 10.3. Possible causes of Mix Deficiencies in Hot-mix Asphalt

Aggregate too wet	Inadequate bunker separation	Aggregate feed gates not properly set	Over-rated dryer capacity	Dryer set too steep	Improper Dryer operation	Temp indicator out of adjustment	Aggregate temperature too high	Worn out screens	Faulty screen operation	Bin overflows not functioning	Leaky bins	Segregation of aggregate in bins	Carryover in bins due to overloading screens	Aggregate scales out of adjustment	Improper weighing	Feed of mineral filter not uniform	Insufficient aggregates in hot bins	Improper weighing sequence	Insufficient asphalt	Too much asphalt	Faulty distribution of asphalt aggregate	Asphalt Scales out of adjustment	Asphalt Meter out of adjustment	Undersize or oversize batch	Mixing time not proper	Improperly set or worn paddles	Faulty Dump Gate	Asphalt and Aggregate feed not Synchronised	Occasional Dust Shakedown Bins	Irregular Plant Operation	Faulty Sampling	Types of Deficiencies that may be encountered in producing plant-mix paving mixtures
		A												B	B				A	A	A	B	C	B	B	B		C			A	Asphalt content does not check Job Mix Formula
		A	A					B	B	B	B	A	A	B	B	B	A							B		B	B	C	B		A	Aggregate gradation does not check Job Mix Formula
	A	A							B	B	B	A	A	B	B	B	A							B	B			C	B		A	Excessive Fines Mix
A			A	A	A	A	A																							A		Uniform Temperatures difficult to maintain
											B			B	B									B								Truck weights do not check batch weights
														B	B					A	A	B	C	B		B		C				Free asphalt on Mix in Truck
																			B								B					Free dust on Mix in Truck
A			A	A	A	A															A	B	C	B	B	B		C		A		Large aggregate uncoated
									B	B	A	A	A	B	B	B	A	B			A	B	C		B	B	B		B	A		Mixture in truck not uniform
																		B			A			B	B	B				A		Mixture in truck fat on one side
					A															A	A	B	C	B				C		A		Mixture flattens in Truck
		A			A	A	A																							A		Mixture burned
A			A	A	A	A			B										A			B	C	B				C		A		Mixture to Brown of Gray
														B	B	B	A			A	A	B	C	B				C		A		Mixture too fat
					A	A	A																							A		Mixture smokes in truck
A			A	A	A	A																								A		Mixture steams in truck
					A	A	A													A										A	A	Mixture appears dull in truck

(Source : Asphalt Institute MS4)

A Applies to batch and drum-mix facilities/ B Applies to batch facilities / C Applies to drum-mix plant facilities

10.5.3.2. Procedure for sampling at HMP, stockpile and truck : The procedure for sampling of bituminous plant mixes at the place of manufacture (HMP), from a stockpile and from a truck, outlined in AASHTO T168, (ASTM D979) and considered suitable for Indian conditions are given below in sub-paras (a), (b) and (c) respectively:

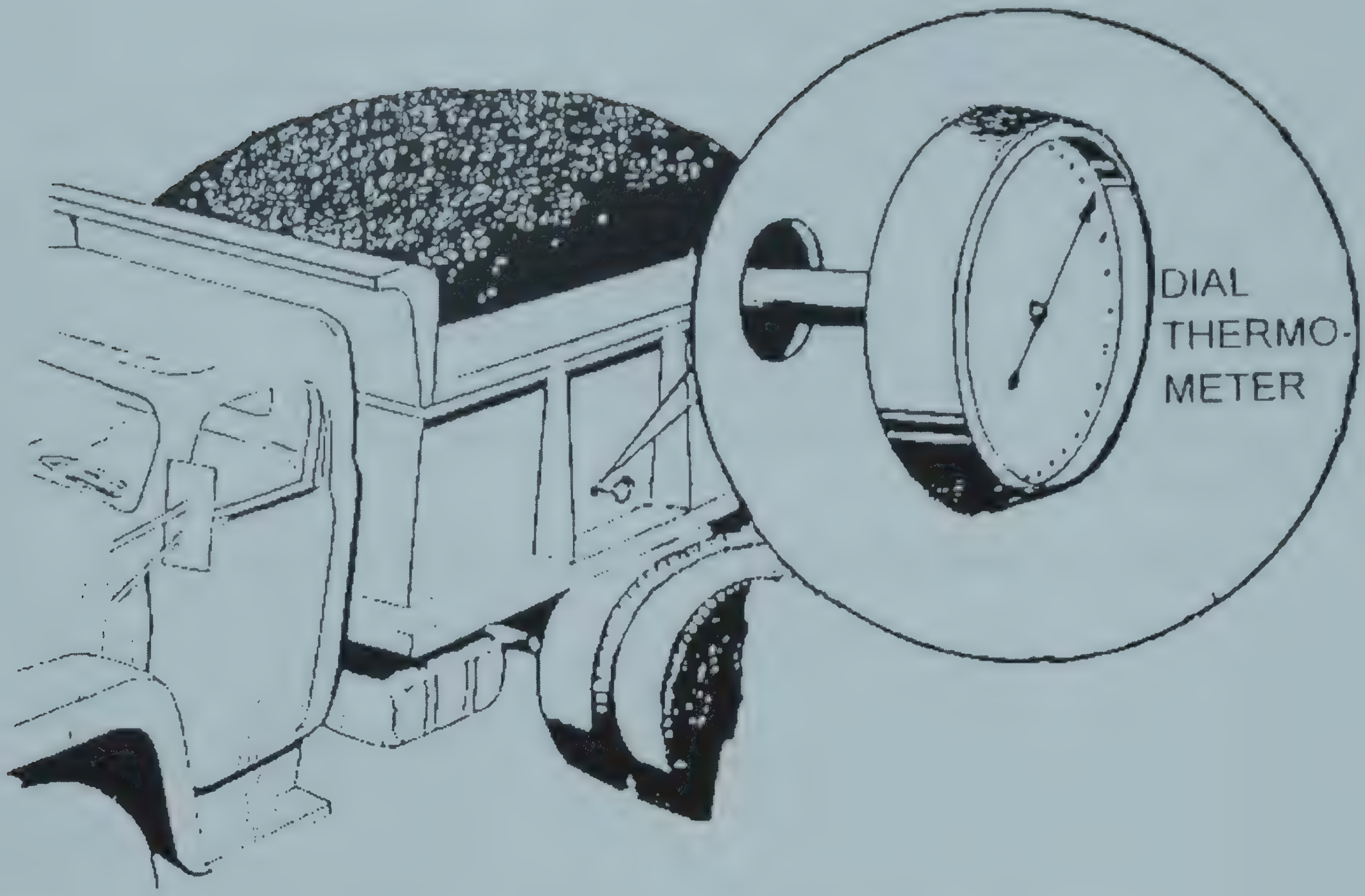


Fig. 10.5. Measuring Temperature of Mix in the Truck

(a) From the pile of a batch, freshly discharged from the mixing plant, a sample should be taken by means of a scoop or shovel scraped from the bottom to the top of the pile at two points 180° from each other, and reduced to the required sizes of samples for different nominal maximum particle sizes are given below in Table 10.4

Table 10.4. Size of Sample

Nominal Maximum Size of Particles, Passing Sieve Size	Minimum Weight of Uncompacted Mixture (kg)
2.36 mm	2
4.75 mm	2
9.5 mm	4
12.5 mm	6
19.0 mm	8
25.0 mm	10
37.5 mm	12
50.0 mm	16

Where it is intended to take a sample, representative of more than one batch of the mixture, samples should be taken at regular intervals from subsequent batches following the same procedure as described above and placed in a suitable container. When the required number of batches have been sampled, the entire amount should be reduced to the required size by mixing and quartering.

A sample should represent not more than one day's run.

The mixture may be warmed, if so required, for purposes of re-mixing, carefully avoiding any overheating of any part of the sample.

Where the purpose of sampling is to determine uniformity of the plant mix, the samples should be handled separately and not mixed together.

(b) From a stockpile, samples should be taken from holes dug into points near the top, middle and bottom of the stockpile in equal quantities. Reduction of the sample to the required size should be carried out as in (a) above.

PLANT INSPECTOR'S DAILY REPORT

Name of Project .... Place .... Date ....

Material Mixed By .... At .... Job Site ....

Consigned To .... At .... Road Project ....

Type of Plant .... Mix Time Per Batch ....

MATERIALS

BITUMEN	Grade	Source			Truck No.			Date Received	Amount
AGGREGATE	Type	Source	63 mm	50 mm	37.5 mm	25 mm	19 mm	....	0.075 mm
Coarse									
Fine									
Filler									
Combined Gradation									
Job Mix Formula									

ANALYSIS OF HOT BIN AGGREGATES

BIN No.	63mm	50mm	37.5mm	25mm	19mm	12.5mm	9.5mm	4.75mm	2.36mm	_____	0.075 mm
1											
2											
3											
4											
Mineral Filler											

Sand Equivalent Value ....

BATCH WEIGHTS

MIX TYPE	BIN 1	BIN 2	BIN 3	BIN 4	FILLER	BITUMEN	TOTAL
% of Total Mix Weight (kg)							100

ANALYSIS OF MIX

SAMPLE	HOUR	TEMP °c	63mm	50mm	37.5mm	25mm	19mm	12.5mm	....	0.075 mm
Average for day										
Job Mix Formula										

TEMPERATURES OF MIX

TIME	08 AM	9.30 AM	11.20 AM	....	6 PM
°C					

CHARACTERISTICS OF MIX

SAMPLE LOCATION	TIME or LOAD No.	THEORETICAL DENSITY	SPECIMEN DENSITY	% THEORETICAL DENSITY	STABILITY	FLOW
From Truck						

WEATHER .... AM .... PM .... TEMPERATURE .... AM ....°C PM .... °C

FROM ....

TO ....

	PRODUCTION	**TYPE OF MIX**
TONS PREVIOUS	....	....
TONS TODAY	....	....
TONS TOTAL	....	....

SAMPLE No .... REPRESENTS .... TONS OF .... FOR DATES ....

SAMPLE No .... REPRESENTS .... TONS OF .... FOR DATES ....

SIGNED ....

(PLANT INSPECTOR)

Fig. 10.6. Plant Inspector's Daily Reporting Format (Source : Asphalt Intitute MS4)

(c) From a truck carrying the mix, samples should be taken from at least 6 points about 0.3 m below the surface, so distributed over the truck that they lie at the midpoints of sections representing one sixth of the superficial area of the truck, formed by a median line running length-wise of the truck and two cross lines dividing the length of the car into equal thirds. If a greater number of samples are required, they should be taken at points spaced according to some regular geometric pattern. These portions should be mixed and reduced by quartering to the required size as given in Table 10.4.

10.5.3.3. Frequency of sampling : As a general guide it is good practice to sample frequently when the operation first commences, in order to gauge the consistency and reliability of the plant. Frequent sampling however tends to interfere with the production, and in order not to slow down the work, sampling should be reduced to a regular norm, once confidence in the plant has been established.

The Paving mixes being subjected to tests must be of a representative nature. Random sampling should be resorted to.

Test results of samples of mix, which do not represent the total material quality, may be misleadin and may not serve the purpose of testing.

Sample testing not only throws light on the quality of the material but also gives important clue regarding the plant's capacity to deliver uniform type of mix and if there is anything wrong during transportation, handling, laying and compaction of mix.

A schedule of sampling and testing suggested by the Asphalt Institute of USA is given in Table 10.5.

Table 10.5. Schedule of Sampling and Testing (Suggested by the Asphalt Institute of USA)

Sample of	Minimum Sample Frequency(1)	Minimum Size of Sample(2)	Test to be Performed
Cold Aggregate	As Necessary(1)	See Table 10.6	Sieve Analysis Specific Gravity Sand Equivalent (When required)
Each Hot-Bin	2 Daily	See Table 10.6	Sieve Analysis Sand Equivalent (when required)
Hot Aggregate, Combined	2 Daily	See Table 10.6	Sieve Analysis
Mineral Filler	As Necessary(1)	See Table 10.6	Sieve Analysis
Asphalt	2 for each transport delivered(4)	1 litre	Send to Central Laboratory
Uncompacted Mix	2 Daily	9 kg	Complete Extraction
Uncompacted Mix	2 Daily	7 kg	Density Stability

Note: (1) Sample frequency will be governed by instructions of the contracting agency and by the immediate conditions surrounding the given project.

(2) Sample size may be governed by instructions of the contracting agency. For special conditions sample size may vary.

(3) In batch plants, each hot bin sample should be taken from the flow of material from the bin gate in increments from several successive batches, and in continuous mix plants several increments spaced several seconds apart.

(4) One sample for check testing and one sample to hold in reverse if question arises.

Table 10.6. Size of Samples

Nominal Maximum Size of Particles, Passing Sieve Size	Minimum Weight of Samples (kg)
Fine Aggregate	
2.36 mm	5
4.75 mm	5
Coarse Aggregate	
9.5 mm	5
12.5 mm	12
19.0 mm	15
25.0 mm	25
37.5 mm	30
50.0 mm	40
63 mm	45
75 mm	60
90 mm	65

10.5.3.4. Packing and labelling : The materials should be properly packed in clean containers with no leakage to ensure that no quantity of the material is lost in transit.

The samples and containers should be clearly and durably marked and should also contain essential information regarding the sample like:

1. Date of collection.
2. Sample number.
3. Location.
4. Type of material
5. Remarks, if any. In case of samples collected at the laying site, a location should be recorded, chainage and which laying strip.

Important information which should also be noted is the area that is covered by a single truck load. For a set strip width, the width and length should be recorded. If then one truck proves to have substandard material, the problem of rectification is limited to the area involved in the one truck load.

10.6. Tests for Materials; Standards and Acceptance Criteria

Standards to be met by all materials after processing, are defined in the Specifications. The minimum frequency of testing varies with the type of material and is given in Table 10.7. The types of testing required are listed and commented on below:

10.6.1. Tests for aggregates : The following tests are carried out for aggregates used in bituminous construction (see para 3.3.3):

1. Deleterious material and cleanliness.
2. Plasticity, Index on material passing 0.425 mm sieve
3. Aggregate Impact Value/Los Angeles Abrasion Value.
4. Specific gravity and bulk density.
5. Flakiness Index and Elongation Index.

6. Stripping Value of Aggregates
7. Water absorption.
8. Gradation.
9. Polished Stone Value
10. Durability
11. Percentage of fractured faces (gravel).

10.6.2. Tests for binder : For paving bitumen the criteria for conformity as per IS:73 requires 3 essential tests to be carried out viz. softening point, penetration and ductility.

For cutback bitumen, the criteria for conformity as per IS:217 requires 3 essential tests to be carried out viz. kinematic viscosity, flash point and ductility.

For bituminous emulsions, as per IS:8887, the various tests to be conducted are listed at Table 1 of the Standard.

10.6.3. Tests for temperature of binder, hot aggregates and mixes : The temperature of binder at the time of spraying and pre-mixing is checked frequently at close intervals. The tests for temperature of hot aggregates and the mix at the mixer and at the time of laying and rolling are also carried out at regular intervals.

10.6.4. Tests for rate of spread of binder and aggregates : For specifications involving binder to be sprayed and aggregates to be spread, the rate of spread is to required to be checked. At least one test per 500 sq m of area of work done is a good norm.

10.6.5. Tests on mixes : The following tests are conducted on premixed material :

1. Aggregate grading, individual sizes before mixing and combined aggregate before placing in mix and after extraction.
2. Stability, flow value and density - void analysis.
3. Hardness number (mastic asphalt).
4. Water sensitivity.
5. Binder content.
6. Density of compacted layer.
7. Thickness of compacted layer.

The frequency of tests is indicated in the Table 10.7.

10.6.6. Non-destructive and destructive methods during quality control : At the site, after the final rolling has been done, the job can be checked by 'Non-destructive' and 'Destructive' methods for meeting the specified density, as under :

(a) Non-destructive Method

After the final rolling has been-carried out, a Nuclear Density Gauge (Fig. 10.7) is placed on the mat and density of compacted layer is determined immediately, while the mat is still hot. This method has the advantage that the Contractor immediately gets to know whether the specified density has been achieved or not. In case the specified density has not been achieved, he still has the time to carry out further rolling, since the mix is still hot enough, to attain the specified density.

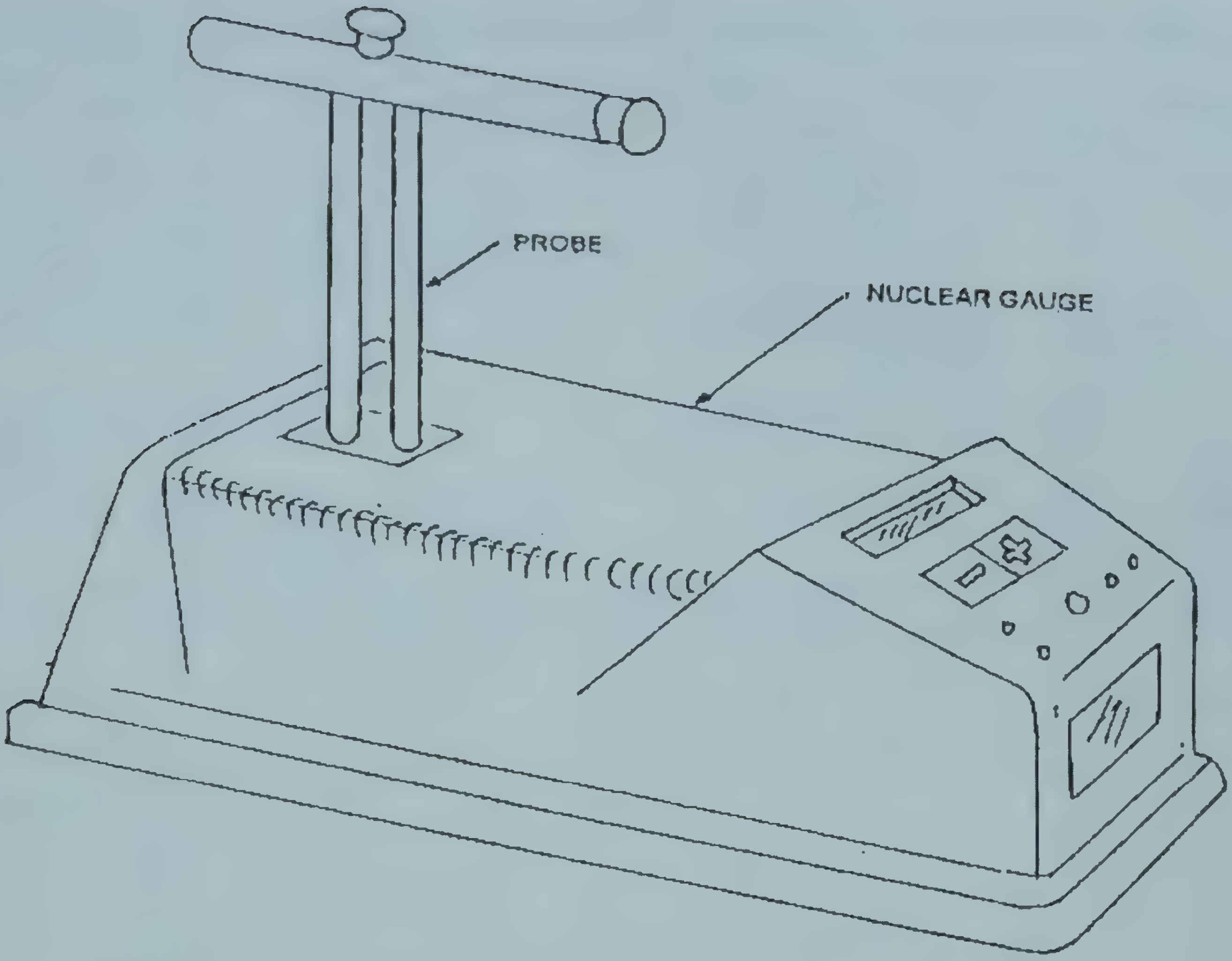


Fig. 10.7. Nuclear Density Gauge

(b) Destructive Method

In this method, a core is cut out from the completed mat after the mat has cooled down, generally the next day. A series of tests are conducted on the extracted core including its density, stability, flow, percent air voids and the percent voids filled by bitumen etc. This method suffers from the serious disadvantage that in case the specified density has not been achieved, it is too late to carry out any further rolling, since the mat is too cold to be subjected to further rolling.

10.6.7. Acceptance criteria : For hot-mix hot-laid mixes, the density and stability values should conform to the following acceptance criteria :

Mean value is not less than the specified value plus times the standard deviation.

$$\left[1.65-\frac{1.65}{(\text{No. of samples})^{0.5}}\right]$$

The permissible variations from the Job Mix Formula for aggregates and binder in respect of Dense Bituminous Macadam, Bituminous Concrete and Semi-dense Bituminous Concrete are given in Table 10.8.

10.7. Quality Control of Finished Pavement

Besides the various controls on the quality of bituminous binder, aggregates and bituminous mixtures as already described, appropriate controls have to be exercised just after the construction is complete, on the finished pavement. The various field controls on the finished pavement are:-

- Surface Texture
- Surface Tolerance

Table 10.7. Control Tests for Bituminous Works and their Minimum Frequency

Sl. No.	Type of Construction	Test		Test Method	Frequency (min.)
1.	Prime Coat/Tack Coat/ Fog Spray	(i)	Quality of binder	IS:73; IS:217 or IS:8887, as applicable	Number of samples per lot and tests as per IS:73, IS:2017 and IS:8887, as applicable
		(ii)	Binder temperature for application		At regular close intervals
		(iii)	Rate of spread of Binder		One test per 500 m^2 and not less than two tests per day.
2.	Seal Coat/Surface Dressing	(i)	Quality of Binder	IS:73; IS:217 or IS:8887, as applicable	Same as mentioned under Serial No. 1
		(ii)	Aggregate Impact Value/Los Angeles Abrasion Value	IS:2386 Part 4	One test per 50 m^3 of aggregate
		(iii)	Flakiness Index and Elongation Index	IS:2386 Part I	-do-
		(iv)	Stripping value of aggregates	IS:6241	Initially one set of 3 representative specimens for each source of supply. Subsequently when warranted by changes in the quality of aggregates
		(v)	Water absorption of aggregates	IS:2386 Part 3	-do-
		(vi)	Water sensitivity of mix	AASHTO T283	-do- (if required)
		(vii)	Grading of aggregates	IS:2386 Part 1	One test per 25 m^3 of aggregate
		(viii)	Soundness (Magnesium and Sodium Sulphate)	IS:2386 Part 5	Initially, one determination by each method for each source of supply, then as warranted by change in the quality of the aggregates.
		(ix)	Polished stone value	BS 812 Part 114	As required
		(x)	Temperature of binder at application		At regular close intervals
		(xi)	Rate of spread of materials		One test per 500 m^2 of work, and not less than two tests per day
		(xii)	Percentage of fractured faces	IS:2386 Part 1	When gravel is used, one test per 50 m^3 of aggregate
3	Open-graded Premix Surfacing/ Close-graded Premix Surfacing	(i)	Quality of binder	IS:73; IS:8887, as applicable	Same as mentioned under Serial No. 1
		(ii)	Aggregate Impact Value/Los Angeles Abrasion Value	IS:2386 Part 4	Same as mentioned under Serial No.2
		(iii)	Flakiness Index and Elongation Index	IS:2386 Part 1	-do-
		(iv)	Stripping value	IS:6241	-do-
		(v)	Water absorption of aggregates	IS:2386 Part 3	-do-

Sl. No.	Type of Construction	Test		Test Method	Frequency (min.)
		(vi)	Water sensitivity of mix	AASHTO T283	Same as mentioned under Serial No. 2
		(vii)	Grading of aggregates	IS:2386 Part 1	-do-
		(viii)	Soundness (Magnesium and	IS:2386 Part 5	-do-
		(ix)	Polished stone value	BS:812 Part 114	As required
		(x)	Temperature of binder at application		At regular close intervals
		(xi)	Binder content		One test per 500m^3 and not less than two tests per day
		(xii)	Rate of spread of mixed material		Regular control through checks of layer thickness
		(xiii)	Percentage of fractured faces	IS:2386 Part 1	Same as mentioned under Serial No. 2
4.	Bituminous Macadam	(i)	Quality of binder	IS:73	Same as mentioned under Serial No. 1
		(ii)	Aggregate Impact Value/Los Angeles Abrasion Value	IS:2386 Part 4	Same as mentioned under Serial No. 2
		(iii)	Flakiness Index and Elongation Index	IS:2386 Part 1	-do-
		(iv)	Stripping Value	IS:6241	-do-
		(v)	Water sensitivity of mix	AASHTO T283	-do-
		(vi)	Grading of aggregates	IS:2386 Part 1	Two tests per day per plant both on the individual constituents and mixed aggregates from the dryer
		(vii)	Water absorption of aggregates	IS:2386 Part 3	Same as in Serial No. 2
		(viii)	Soundness (Magnesium and Sodium Sulphate)	IS:2396 Part 5	-do-
		(ix)	Percentage of fractured faces	IS:2386 Part 1	Same as mentioned under Serial No. 2
		(x)	Binder content and aggregate grading		Periodic, subject to minimum of two tests per day per plant
		(xi)	Control of temperature of binder and aggregate for mixing and of the mix at the time of laying and rolling		At regular close intervals
		(xii)	Rate of spread of mixed material		Regular control through checks of layer thickness
		(xiii)	Density of compacted layer		One test per 250 m^2 of area
5.	Bituminous Penetration Macadam/ Built-up Spray-Grout	(i)	Quality of binder	IS:73; IS:217 or IS:8887, as applicable	Same as mentioned under Serial No. 1
		(ii)	Aggregate Impact Value/Los Angeles Abrasion Value	IS:2386 Part 4	One test per 200 m^3 of aggregate
		(iii)	Flakiness Index and Elongation Index	IS:2386 Part 1	-do-
		(iv)	Stripping value	IS6241	Same as mentioned under Serial No. 2

Sl. No.	Type of Construction	Test	Test Method	Frequency (min.)
		(v) Water absorption of aggregates	IS:2386 Part 3	-do-
		(vi) Water sensitivity of mix	AASHTO T283	-do-, if required
		(vii) Aggregate grading	IS:2386 Part 1	one test per 100 m^3 of aggregate
		(viii) Soundness (Magnesium and Sodium Sulphate)	IS:2386 Part 5	Same as mentioned under Serial No. 2
		(ix) Percentage of fractured faces	IS: 2386 Part 1	-do-
		(x) Temperature of binder at application		At regular close intervals
		(xi) Rate of spread of binder		Same as mentioned under Serial No. 2
6.	Dense Bituminous Macadam/Semi Dense Bituminous Concrete/ Bituminous Concrete	(i) Quality of binder	IS:73	Same as mentioned under Serial No. 1
		(ii) Aggregate Impact Value/ Los Angeles Abrasion Value	IS:2386 Part 4	Same as mentioned under Serial No.2
		(iii) Flakiness Index and Elongation Index	IS:2386 Part 1	-do-
		(iv) Stripping Value	IS:6241	-do-
		(v) Soundness Magnesium	IS:2386 Part 5	-do-
		(vi) Water absorption of aggregates	S:2386 Part 3	-do-
		(vii) Sand equivalent test	IS:2720 Part 37	As required
		(viii) Plasticity Index	IS:2720 Part 5	As required
		(ix) Polished stone value	BS:812: Part 114	As required, for Semi Dense Bituminous Concrete/ Bituminous Concrete
		(x) Percentage of fractured faces	IS:2386 Part 1	Same as mentioned under Serial No. 2
		(xi) Mix grading		One set of tests on individual constituents and mixed aggregate from the dryer for each 400 tonnes of mix subject to a minimum of two tests per plant per day
		(xii) Stability of Mix	ASTM D1559	For each 400 tonnes of mix produced, a set of 3 Marshall specimens to be prepared and tested for stability, flow value, density and void content subject to a minimum of two sets being tested per plant per day
		(xiii) Water sensitivity of mix (Retained Tensile Strength)	AASHTO T283	Same as mentioned under Serial No. 2, if required

Sl. No.	Type of Construction	Test	Test Method	Frequency (min.)
		(xiv) Control of temperature of binder in boiler, aggregate in the dryer and mix at the time of laying and rolling		At reular close intervals
		(xv) Control of binder content and grading of the mix	AASHTO T-168, AASHTO T-164	One test for each 400 tonnes of mix subject to a minimum of two tests per day per plant
		(xvi) Rate of spread of mixed material		Regular control through checks on the weight of mixed material and laer thickness
		(xvii) Density of compacted layer		One test per 250 m^2 area
7.	Mastic Asphalt	(i) Quality of binder	IS:1203; IS:1205, IS:1212; IS:1216; IS:1217	Same as mentioned under Serial No. 1
		(ii) Aggregate Impact Value/ Los Angeles Abrasion Value	IS:2386 Part 4	Same as mentioned under Serial No. 2
		(iii) Flakiness Index and Elongation Index	IS:2386 Part 1	-do-
		(iv) Stripping Value	IS:6241	-do-
		(v) Water sensitivity of mix	AASHTO T 283	-do-
		(vi) Grading of aggregates	IS:2386 Part 1	Two tests per day per plant both on the individual constituents and mixed aggregates from the dryer
		(vii) Water absorption of aggregates	IS:2386 Part 3	Same as mentioned under Serial No. 2
		(viii) Soundness (Magnesium and Sodium Sulphate)	IS:2386 Part 5	-do-
		(ix) Percentage of fractured faces	IS:2386 Part 1	-do-
		(x) Binder content and aggregate grading	AASHTO 1168 AASHTO T164	Periodic, subject to minimum of two tests per day per plant
		(xi) Control of temperature of binder and aggregate for mixing and of the mix at the time of laying and rolling		At regular close intervals
		(xii) Rate of spread of mixed material		Regular control through checks of layer thickness
		(xiii) Hardness number	IS:1195-1978	one test for each 400 tonnes of mix subject to a minimum of two tests per day
8.	Slurry seal	(i) Quality of binder	IS:8887	Same as mentioned under Serial No. 1.
		(ii) Film stripping test	IS:6241	Initially one set of 3 representative specimens for each source of supply, then as warranted by changes in the quality of aggregates
9.	Recycled material	(i) Binder content and aggregate grading	AASHTO T-1 68 AASHTO T164	Minimum of one test per 25 m^3 of recycled material

Sl. No.	Type of Construction	Test	Test Method	Frequency (min.)
		(ii) Recovered binder penetration	IS:1203	Minimum of one test per 50m^3 of recycled material
		(iii) Mix stability (Remix/Repave)	ASTM D1559	For each 400 tonnes of mix recycled, a set of 3 Marshall specimens to be prepared and tested for stability, flow density and void content, subject to a minimum of two sets of tests per day
10.	High Performance Base	(i) Quality of binder	IS:73	Same as mentioned under Serial No. 1
		(ii) Aggregate Impact Value/ Los Angeles Abraision Value	IS:2386 Part 4	Same as mentioned under Serial No. 2
		(iii) Flakiness Index and Elongation Index	IS:2386 Part 1	-do-
		(iv) Stripping Value	IS:6241	-do-
		(v) Soundness (Magnesium and Sodium Sulphate)	IS:2386 Part 5	-do-
		(vi) Water absorption of aggregates	IS:2386 Part 3	-do-
		(vii) Sand equivalent test	IS:2386 Part 37	As required
		(viii) Plasticity Index	IS: 2386 Part 5	As required
		(ix) Polished stone value	BS:812 Part 114	As required
		(x) Percentage of fractured faces	IS:2386 Part 1	Same as mentioned under serial No. 2
		(xi) Mix grading		One set of tests on individual constituents and mixed aggregate from the dryer for each 400 tonnes of mix subject toa minimum of two tests per plant per day
		(xii) Stiffness and deformation resistance/ indirect tensile strength	BS:DD213 BS:DD226 ASTM D4867	For each set of 400 tonnes of mix produced, one set of 3 samples, subject to a minimum of two sets per plant per day, for high performance base.
		(xiii) Density and void content		For each set of 400 tonnes of mix produced, one set of 3 samples, subject to a minimum of two sets per plant per day
		(xiv) Percentage Refusal Density	BS598 Part 104	-do-
		(xv) Water sensitivity of mix	AASHTO T-283	Same as mentioned under Serial No.2, if required
		(xvi) Control of temperature of binder in boiler, aggregate in the dryer and mix at the time of laying and rolling		At regular close intervals

Sl. No.	Type of Construction	Test	Test Method	Frequency (min.)
		(xvii) Control of binder content and grading of the mix	AASHTO T-168 AASHTO T-164	One test for each 400 tonnes of mix subject to a minimum of two tests per day per plant
		(xviii) Rate of spread of mixed material		Regular control and through checks on the weight of mixed material and layer thickness
		(xix) Density of compacted layer		One test per 250 m^2 area
11.	Stone Mastic Asphalt	(i) Quality of binder	IS:73; IRC:SP:53	Same as mentioned under Serial No. 1
		(ii) Aggregate Impact Value/Los Angeles Abrasion Value	IS:2386 Part 4	Same as mentioned under Serial No. 2
		(iii) Flakiness Index and Elongation Index	IS:2386 Part 1	-do-
		(iv) Stripping Value	IS:6241	-do-
		(v) Soundness (Magnesium and Sodium Sulphate)	IS:2386 Part5	-do-
		(vi) Water absorption of aggregates	IS:2386 Part 3	-do-
		(vii) Sand equivalent test	IS:2720 Part 37	As required
		(viii) Plasiticity Index	IS:2720 Part 5	As required
		(ix) Polished stone value	BS:812 Part 114	As required
		(x) Percentage of fractured faces	IS2386 Part 1	Same as mentioned under Serial No. 2
		(xi) Mix grading	AASHTO T-168 AASHTO T-164	One set of tests on individual constituents and mixed aggregate from the dryer for each 400 tonnes of mix subject to a minimum of two tests per plant per day
		(xii) Stiffness and deformation resistance/indirect tensile strength	BS:DD 213 BS:DD 226 ASTM D4867	For each set of 400 tonnes of mix produced, one set of 3 samples, subject to a minimum of two sets per plant per day, for high performance base.
		(xiii) Density and void content		For each set of 400 tonnes of mix produced, one set of 3 samples, subject to a minimum of two sets per plant per day.
		(xiv) Percentage Refusal Density	BS:598 part 104	-do-
		(xv) Water sensitivity of mix	AASHTO T-283	Same as mentioned under Serial No. 2
		(xvi) Control of temperature of binder in boiler, aggregate in the dryer and mix at the time of laying and rolling		At regular close intervals
		(xvii) Control of binder content and grading of the mix	AASHTO T-168 AASHTO T-164	One test for each 400 tonnes of mix subject to a minimum of two tests per day per plant
		(xviii) binder drainage test	BS:DD232	-do-

Sl. No.	Type of Construction	Test		Test Method	Frequency (min.)
		(xix)	Fibre content test		-do-
		(xx)	Rate of spread of mixed material		Regular control and through checks on the weight of mixed material and layer thickness
		(xxi)	Density of compacted layer		One test per 250 m^2 area
12.	Cold Mix	(i)	Quality of binder	IS:8887;IS:217; AASHTO M140; AASHTO M 208, as applicable	Same as mentioned under Serial No. 1
		(ii)	Aggregate Impact Value/Los Angeles Abrasion Value	IS:2386 Part 4	Same as mentioned under Serial No. 2
		(iii)	Flakiness Index and Elongation Index	IS:2386 Part 1	-do-
		(iv)	Stripping Value	IS:6241	-do-
		(v)	Water sensitivity of mix	AASHTO T-283	-do-
		(vi)	Grading of aggregates	IS:2386 Part 1	Two tests per day per plant both on the individual constiuents and mixed aggregates from the dryer
		(vii)	Percentage minimum coating		Two tests per day per plant
		(viii)	Water absorption of aggregates	IS:2386 Part 3	Same as mentioned under Serial No. 2
		(ix)	Soundness (Magnesium and Sodium Sulphate)	IS:2386 Part 5	-do-
		(x)	Percentage of fractured faces	IS:2386 Part 1	When gravel is used, one test per 50m^3 of aggregate
		(xi)	Binder content and aggregate grading	AASHTO T-168 AASHTO T-164	Periodic, subject to minimum of two tests per day per plant
		(xii)	Mix stability	Ashphalt Institute MS-14, Appendix F and Appendix H	For each 400 tonnes of mix producted, one set of 3 Marshall specimens to be prepared and tested for stability, flow, density and void content, subject to minimum of two sets of tests per plant per day
13.	Sand Asphalt Base course	(i)	Quality of binder	IS:73	Same as mentioned under Serial No. 1
		(ii)	Los Angeles Abrasion Value	IS:2386 Part 4	Same as mentioned under Serial No. 2
		(iii)	Sand equivalent test	IS:2720 Part 37	As required
		(iv)	Plastictity Index	IS:2720 Part 5	As required
		(v)	Mix grading	IS:2386 Part 1	One set of tests on individual constituents and mixed aggregate from the dryer for each 400 tonnes of mix subject to a minimum of two tests per plant per day

Sl. No.	Type of Construction	Test		Test Method	Frequency (min.)
		(vi)	Stability of Mix	IS:2386 D 1559	For each 400 tonnes of mix produced, a set of 3 Marshall specimens to be prepared and tested for stability, flow value, density and void content subject to a minimum of two sets being tested per plant per day
		(vii)	Control of temperature of binder in boiler, aggregate in the dryer and mix at the time of laying and rolling		At regular close intervals
		(viii)	Control of binder content and grading of the mix	AASHTO 1168 AASTO T164	One test for each 400 tonnes of mix subject to a minimum of two tests perday per plant
		(ix)	Rate of spread of mixed material		Regular control and through checks on the weight of mixed material and layer thickness
		(x)	Density of compacted layer		One test per 250 m^2 area
14.	Modified Binder	(i)	Softening Point	IS:1205	Initially on submission thereafter daily if site blended, weekly if pre-blended
		(ii)	Penetration at 25°C and 4°C	IS:1203	-do-
		(iii)	Elastic Recovery	ASTM D 5976	-do-
		(iv)	Ductility	IS:1208	-do-
		(v)	Flash Point	IS:1209	-do-
		(vi)	Fraass Breaking	IS: 9381	Initially on submission
		(vii)	Viscosity at 150°C	IS:1206	-do-
		(viii)	Thin film over test, penetration, softening point, elastic recovery of residue, loss on heating	IS:9382; IS;1203; IS:1205; ASTM D5976, IS:9382	-do-
15.	Geotextiles	(i)	The requirements of Clause 704.3.1 of the Ministry's Specifications for Road and Bridge Works (Fourth revision) shall apply		

Table 10.8 Permissible Variations from Job Mix Formula

S. No.	Description material	Permissible variation	
		Base/binder course	Wearing course
1.	Aggregate passing 19 mm sieve or larger	±8%	±7%
2.	Aggregate passing 13.2 mm, 9.5 mm	±7%	±6%
3.	Aggregate passing 4.75 mm	±6	±5%
4.	Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	± 5	±4
5.	Aggregate passing 0.3 mm o.15 mm	±4	±3
6.	Aggregate passing 0.075 mm	±2	±1.5
7.	Binder content	±0.3	±0.3
8.	Mixing temperature	±10°C	±10°C

- Compacted Layer thickness
- Compacted Density, which may be determined by one of the following methods:
  - per cent of Laboratory Density
  - per cent of Maximum Theoretical Density
  - Test Section (Control Strip) Density

A Suitable core cutting machine capable of coring 10 cm diameter cores is commonly used for determining the insitu density of a compacted bituminous layer but in many circumstances 15 cm diameter cores are more appropriate as they give a more accurate measure of density and are more suitable for additional tests on the as-laid material when this is required As a measure of expediency, the use of nuclear gauges is also becoming increasingly popular, the testing procedures being both non-destructive and fast. An important element of cutting cores is to verify the adhesion between layers.

The data on density, thickness and air voids etc. obtained from field tests are statistically analysed to see that the various requirements of the job mix formula are indeed satisfied. A core cutting machine, and a moving straight edge are shown in Figs 10.8 and 10.9 respectively. A well finished pavement with good quality control exercised during construction is shown in Fig 10.10, the various requirements for the surface finish of different types of bituminous layers as set out in Tables 10.1 and 10.2 ,must be satisfied

10.8. Laboratory Facility

10.8.1. Present set-up in India : For carrying out control tests and checks on quality the Department normally has laboratory facilities at three levels:-

(i) The field laboratory,

(ii) The regional laboratory, and

(iii) The central laboratory.

10.8.1.1. The field laboratory : The field Laboratory at the Division Level is equipped with all implements and appliances for collection of samples, and for carrying out all basic routine tests of simple nature required for checking day-to-day construction work.

The laboratory also has arrangements for packing, preservation and transportation without damage of samples which may require to be sent to the regional laboratory.

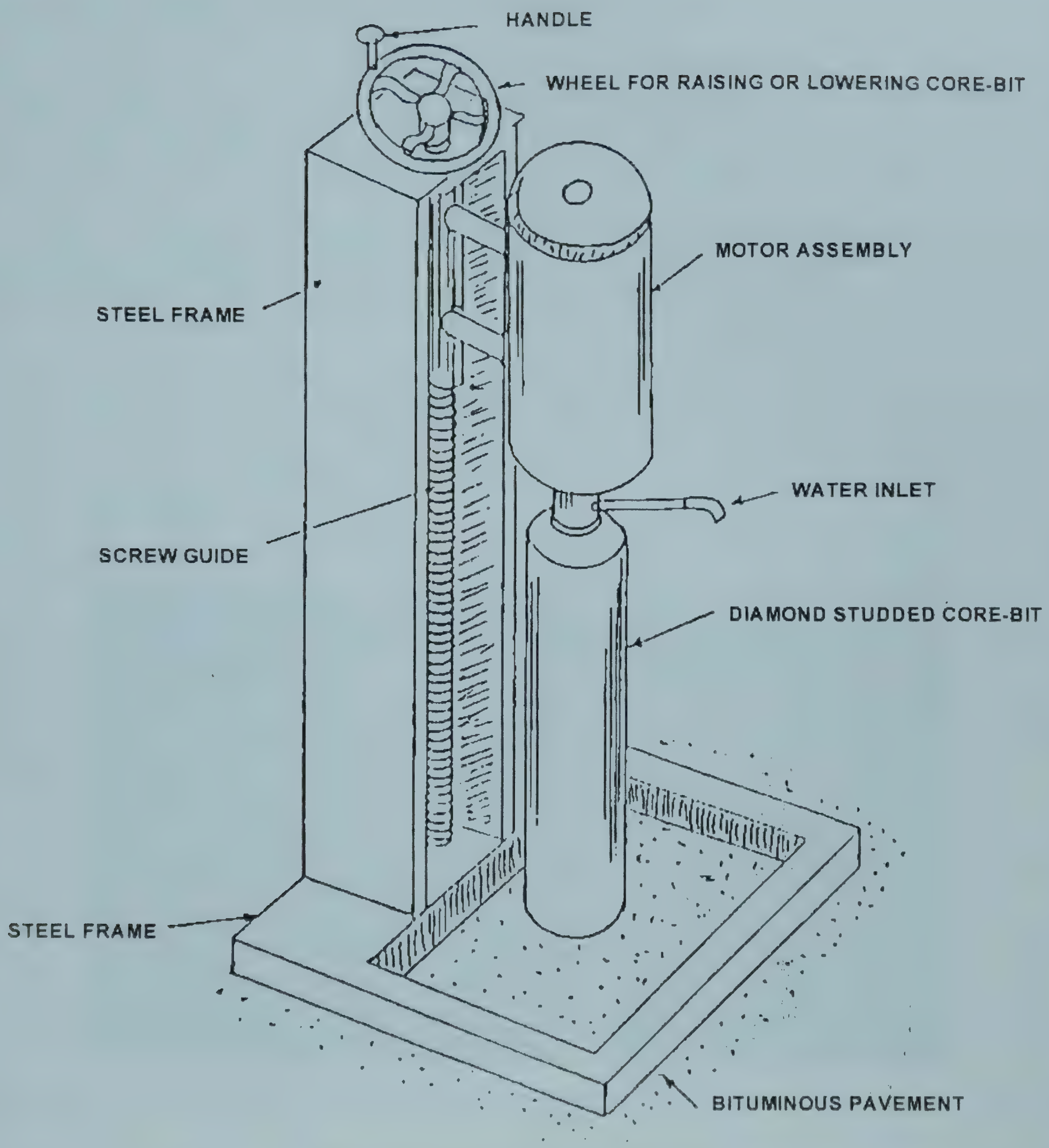

HANDLE
WHEEL FOR RAISING OR LOWERING CORE-BIT
MOTOR ASSEMBLY
STEEL FRAME
WATER INLET
SCREW GUIDE
DIAMOND STUDDED CORE-BIT
STEEL FRAME
BITUMINOUS PAVEMENT

Fig . 10.8 A Core Cutting Machine

A system for the correct labelling, and identification of samples, and an adequate facility for documentation and recording of test results and presentation of record is adopted.

Generally, a junior Engineer of the Division, with aptitude for testing work is the head of the unit directly under the control of the Executive Engineer. He is generally trained by the Central or Regional Laboratory. Adequate number of Laboratory Assistants and Research Assistants, depending upon the workload will assist him in his work.

1.8.1.2. Provision of laboratory : As per present day contract agreements for important project woks, the responsibility for equipping, running and bearing the cost of testing work is that of the agency responsible for the

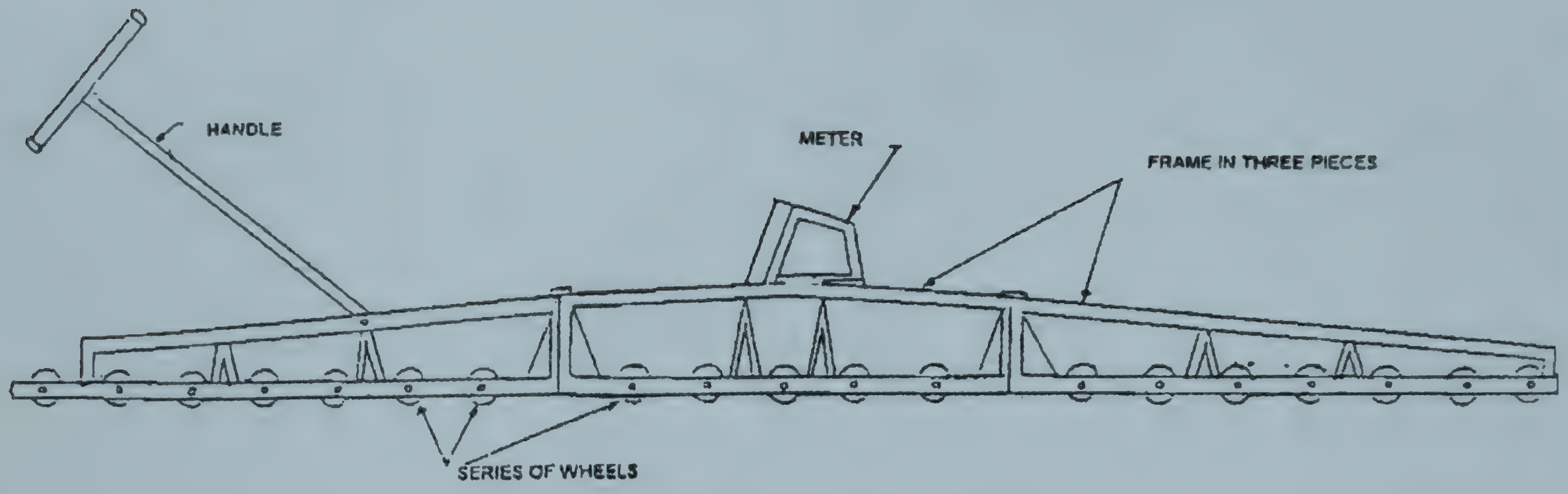


Fig. 10.9. Moving Straight Edge

Fig. 10.10. A View of a Well Finished Pavement with Good Quality Control Exercised During Construction

work. If so stipulated in the agreement, the agency should also provide such assistance, instruments, machines, labour and materials as are normally required for examining, measuring and testing any work and the quality, weight or quantity of any material used and supply samples of material before their incorporation in the work.

A list of suggested equipment to be provided in the field laboratory is given in ***Appendix-15.***

10.8.1.3. The regional laboratory : The Regional Laboratory in the Circle is headed by an Executive Engineer assisted by the required number of Research Assistants and Laboratory Assistants The R.A' s and L.A.'s are required to have the minimum educational qualification of being science graduates.

The regional laboratory carries out all tests required by the Circle Level quality control team and test works of primary level control team for which equipment is not available in the field.

A list of suggested equipment to be provided in the regional laboratory is the same as for the Central Laboratory, given at ***Appendix-16.***

10.8.1.4. The central laboratory: Generally, the Central Laboratory is the most elaborately equipped laboratory and is located at the headquarters of the zone under the charge of the Chief Engineer.

The Central Laboratory is generally headed by a Director (Superintending Engineer rank).

This laboratory provides testing facilities of specialised nature and acts as a model laboratory for important research schemes in progress in the State.

A list of equipment to be provided in the State Central laboratory is given in ***Appendix-16***.

10.8.2. Recommended Testing Facilities for Large Projects: With the ever-increasing number of large road projects in India, the present trend is towards contract construction wherein the quality of construction work by the Contractor is supervised by the Consultant. The Resident Engineer and his staff at the site control all the field and laboratory testing work involved in quality control. The site laboratory should be equipped with all necessary testing equipment without having to send the samples away from the site, except for such tests as would require highly specialised sophisticated equipment. A List of equipment given at ***Appendix-16.*** broadly covers all the needed items but suitable additions or alternatives may be made depending on the specific requirements for the project.

It is to be recognised that the recommendations for quality control requires the services of a qualified Materials Engineer and technicians well versed with material testing and various in-situ tests etc. The test results must be maintained in a systematic manner. The data should be statistically analysed. The use of "Control charts" will be found very helpful in ensuring that the product is complying with the limits prescribed, the deviations are detected in time and corrective measures applied immediately.

Appendix-1

ANTI-STRIPPING AGENTS USED FOR BITUMINOUS MATERIALS AND MIXES

1. Scope

When the proposed aggregates for use in bituminous mixes or applications fail to meet the bitumen stripping criteria specified and alternative aggregates are not economically available, the use of an anti-stripping agent additive, and details of type, quality and quality and quantity should be worked out This Appendix sets out the tests and other requirements for determining the suitability of a proposed proprietary anti-stripping agent and directions for its use. The addition of a small amount of hydrated lime to a bituminous mix is sometimes used instead of one of the proprietary anti-stripping agents. While hydrated lime is not considered in this Appendix some of the tests given herein would be suitable for assessing its assessing its suitability as an anti-stripping agent.

2. Materials

2.1. Type

The anti stripping agents should be fatty acid amines having a long hydrocarbon chain.

2.2. Physical and Chemical Requirements

The anti-stripping agents should conform to the physical and chemical requirements as detailed in Table A 1.1

2.3 Storage and Handing

Anti-stripping agents should be properly stored in closed containers made of steel or aluminium. Containers made of zinc, copper, polythene, PVC and most types of rubber are not suitable for use. As most of the anti-stripping agents cause irritation when in contact with human skin and are also irritating to the eyes, protective gloves for hands and goggles for the eyes should be used while handling them, specially in case of liquid anti-stripping agents.

3. Use in Sprayed Work

3.1. Additive Dosage

The dosage should be determined depending on the nature (stripping value) of the aggregate and the size of aggregate. While the recommended minimum dose for sprayed work is given in Table A1.2, the actual dosage should be arrived at after laboratory trials using Test 3.

3.2. Mixing Procedure During Construction

The anti-stripping agent supplied in liquid, solid or concentrate form should be thoroughly mixed with the bituminous material proposed for use in the particular application. When used with straight run bitumen, the correct dose of anti-stripping agent should be added in hot bitumen tank boiler and the hot bitumen circulated for thorough mixing before use.

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1 For information on this subject reference may be made, among others, to a Paper by Dr. jain et al in IRC Highway Research Bulletin No 47,1992. The quality of the hydrated lime can be tested using the tests given in is IS :1554.

4. Use in Premix Work

4.1. Additive Dosage

The dosage should be determined depending on the nature (stripping value) of the aggregate and the per cent voids in the mix. While the recommended minimum doses for different types of bituminous premix materials in terms of voids content are given Table A1.3, the actual dosage should be arrived at after laboratory trials using Test 3.

Table A 1.1. Tests and Acceptance Criteria for Anti-Stripping Agents

S No.	Test	Method	Limit
1.	Specific gravity 27°C	IS:1202	0.86-1.03
2.	Pour point °C maximum	IS: 1448	42
3.	Flash point °C minimum	IS: 1448	150
4.	Water content per cent vol., maximum	IS:1448	1.0
5.	Total base value KOH/g minimum	ASTM D664	200
6.	Nitrogen content per cent Wt Minimum	Element Analyser	7.0
7.	Solubility in diesel oil (HDO or LDO) in the ratio of 2:98 at 50°C	Test 1	Complete
8.	Aggregate stripping values at varying additive percentage	IS:6241 Test 2	No stripping at selected additive percentages
9.	Under water coating test	Annexure Test 3	Complete coating at selected additive percentage
10.	Thermal stability at 163°C	Test 4	Should not lose its efficacy
11.	Stability after exposure to air	Test 5	Compklete coating at selected additive percentage
12.	Boiling water test per cent coating, minimum	ASTM D3625	95
13.	Retained Marshall Stability per cent minimum	Test 6	75

Table A 1.2. Tentative Recommended Minimum Dose of Anti-stripping Agent for Sprayed Work

Aggregate stripping value	Dose of antistripping agent in per cent be weight of bitumen			Liquid seal coat
	Surface dressing with precoated aggregate	Penteration Macadam/ Built-up spray grout	Surface Dressing with uncoated aggregate	
0-25	0.5	0.6	0.7	0.8
25-50	0.6	0.7	0.8	1.0
50-100	0.75	1.0	1.0	1.0

4.2. Mixing Procedure During Construction

The required dose of the anti-stripping agent should be poured into the hot bitumen tank and allowed 15 to 30 minutes of circulation or stirred to ensure a homogeneous mix. Alternatively, the correct dose should be injected into the bitumen line by means of a pump. The agent is fed into the bitumen first before it is sprayed on the aggregate in the mix; thus, no separate mixing time for mixing the agent with bitumen is required. In rolled asphalt and bitumen mastic surfacing work, precoated chippings are pressed into the hard surface while the mix is still hot to make the newly laid surface skid resistant. The chipping should be precoated with bitumen treated with anti-stripping compound.

Table A 1.3. Tentative Recommended Minimum Dose of Anti-Stripping Agent in Bitumen Premix Work

Stripping value of Aggregate	Dose of anti-stripping agent in per cent by weight of bitumen		
	Voids content 3-5 per cent	Voids content 5-10 per cent	Voids content 1 10-15 per cent
0-25	0.3	0.4	0.5
25-50	0.4	0.5	0.6
50-100	0.6	0.8	1.0

TEST 1. MISCIBILTY IN BITUMEN USING DIESEL OIL

Procedure : 98 ml of diesel oil (HDO or LDO) and 2 ml of anti-stripping agent should be taken in a measuring cylinder with stopper. The cylinder stopper. the cylinder along with its contents should be kept in a water bath , maintained at 50°C + 1°C for half an hour. It should then be taken out from the water bath and shaken vigorously for 10 minutes. The stopper should be removed and the cylinder kept in the water bath for half bath for half an hour and examined for separation or settlement .

Reporting of results: An anti-stripping agent is reported on be completely soluble in diesel oil if no separation or settlement is observed for half an hour.

TEST 2. AGGREGATE STRIPPING VALUES AT VARYIG ANTI-STRIPPING AGENT PERCENTAGES

(Based on IS: 6241-1971)

Procedure: Coarse aggregate passing a 19 mm sieve and retained on a 13.2 mm sieve should be washed and dried in an oven for 24 hours at 110°C 100 gms of dried sieved coarse aggregate should be heated to 149°C and then mixed with 80/100 penetration grade bitumen at 5 per cent by weight of aggregate and the mixture heated up to 163°C. The mixture should be mixed thoroughly to achieve uniform coating of aggregates by bitumen. The mix should then be transferred to a 500 ml beaker and allowed to cool to room temperature. Distilled water should be added to the beaker, which should be placed in a water bath maintained at 40° ± 1°C for 24 hours. The percentage degree of stripping should be assessed visually. The test should also be conducted with water containing 1 per cent Sodium, Chloride, as a precautionary measure to test for stripping in contaminated water. The test is repeated using bitumen containing up to one per cent of anti-stripping agent, in increments of 0.25 per cent

TEST 3. EFFICATCY OF ANTI-STRIPPING AGENT FOR COATING AGGREGATES WITH BITUMEN IN THE PRESENCE OF WATER

Procedure: The anti-stripping agent should be added in per cent increments of 0.0, 0.25, 0.50. 0.75, 1.00 and 1.25 to cutback bitumen MC 3 (4 parts of bitumen 80/100 and 1 part of kerosene oil). The blends should be used for testing their ability to coat the road aggregates under water

(a) 100 gm of clean and dry stone dust conforming to the following gradation should be taken in a wide mouth bottle:

Sieve Size	Cumulative per cent passing
2.36 mm	100
1.18 mm	80
0.600 mm	75
0.300 mm	45

The bottle should be filled to 3/4 of its volume with distilled water at 40°C. The bitumen anti-stripping agent blend should be added to the bottle at the rate of 7.5 per cent by weight of stone dust. The stopper should be replaced and the bottle should be vigorously shaken for two minutes. The water should be then drained off and the coated stone dust should be transferred to a piece of paper and examined visually for evidence of complete coating. The minimum per cent addition of anti-stripping agent at which the stone dust sample is completely coated should be recorded. The test should be repeated at 60°C in water, in as in a 1 per cent solution of Sodium Chloride in water for both the testing temperatures

(b) The under water coating test should further be conducted with coarse aggregate passing a 19 mm sieve and retained on a 13 mm sieve In this case the per cent addition of the cutback-anti stripping agent blend should be kept at 5 per cent by weight of coarse aggregate. In order to evaluate stripping in contaminated water, the test should also be carried out in a 1 per cent solution of Sodium Chloride in water.

The minimum per cent addition of anti-stripping agent at which the stone dust/coarse aggregate is thoroughly coated in accordance with (a) and (b) should be taken as the dose of anti-stripping agent.

TEST 4. STABILITY OF ANTI-STRIPPIG AGENT SUBJECT TO STORAGE IN HOT BITUMEN

Procedure: Blends of anti-stripping agent and bitumen of 80/100 grade should be prepared with 0.00, 0.25, 0.50 0.75 and 1.00 per cent contents of anti-stripping agent and kept in an oven at 163°C for five hours. After the heat exposure, the blended samples are fluxed with kerosene oil to obtain the consistency of MC 3 and tested in the under water water coating test.

Reporting of test results : An anti-stripping agent should be deemed to be heat resistant if heat resistant if the dose requirement before and after heat exposure remains unchanged.

TEST 5. STABILITY OF ANTI-STRIPPING AGENT SUBJECTED TO EXPOSURE TO AIR

Procedure : About 10 gm of the anti-stripping agent is exposed to air for 2 weeks. Blends of the anti-stripping agent with cut-back bitumen MC -3, varying from 0 to 1.25 per cent by weight of cutback bitumen, are prepared and tested in accordance with Test 3.

TEST 6. UANTITATIVE EVALUATIOLN OF RETAINED MARSHALL STABILITY VALUES AFTER IMMERSION IN WATER

Procedure: A For quantitative evaluation, the tests should be carried out as stipulated in ASTM D1075 (Effect of Water on Cohesion of Compacted Bituminous Mixtures). The gradation of aggregates should be such as to give sufficient voids in the compacted bituminous mix to bring out the effects of stripping, The gradation of aggregates should be as described below:

Sieve Size	**Cumulative per cent passing**
19.00 mm	100
13.20 mm	75 - 100
9.50 mm	60 - 80

4.75 mm	35 - 55
2.36 mm	10 - 22
0.300 mm	6 - 16
0.150 mm	4 - 12
0.075 mm	2 - 8

The Marshall test specimens should be prepared using 5 per cent bitumen of 80 /100 grade by weight of aggregates, blended with varying percentages of anti-stripping agents from 0 to 1 per cent in increments of 0.25 per cent. The test samples should give a void content of about 6 per cent. At least 8 standard Marshall specimens at each of the varying anti-stripping agent percentages should be prepared. Each set of 8 test specimens should be stored in two groups of 4 so that the average specific gravity of the specimens in Group 1 should be essentially the same as in Group II. Group I should be tested for Marshall Stability to the usual procedure described in ASTM D1559 Group II specimens should be immersed in water for 24 Hours at 60°C # 1°C, and should then be tested immediately for Marshall Stability in accordance with ASTMD 1559.

Calculation: The numerical index of resistance of bituminous mixtures to the detrimental effect of water should be expressed as the index of retained stability:

$$\frac{\text{Average Marshall Stability of Group II}}{\text{Average Marshall Stability of Group II}} \times 100 \text{ per cent}$$

Requirement for acceptance: A Minimum of 75 per cent of retained marshall strength should be required for acceptance.

Choice of test to assess the potential for stripping of an aggregate/bitumen mixture

If there is inadequate adhesion between bitumen and aggregate in the presence of water under field conditions the consequences for a bituminous surfaced road can be very serious: not only is a relatively expensive surfacing damaged but to put the matter right can also prove expensive. Therefore, it is very important to determine, preferably in advance of construction, whether there is a potential problem of adhesion between the proposed aggregate and the proposed bitumen type and source.

The test to assess the potential for stripping of an aggregate/bitumen mixture should be as per AASHTO T283.

Appendix-2

SELECTION OF CHIPPING SIZE

The first step in the design of a surface dressing is the selection of the nominal size of the chippings.

As time passes, the action of traffic on a surface dressing gradually forces the shipping into the underlying surface, thus diminishing the surface texture

The embedment process occurs more rapidly when the underlying road surface is soft rather than hard, or when the volume of traffic, particularly of commercial vehicles, is high Accordingly, larger chippings are required on soft surfaces or where traffic is heavy whilst small chippings are best for hard surfaces or light traffic

Commercial vehicles are defined as vehicles with an unladen weight greater than 1.5 tonnes. Table 4.5 shows the chipping sizes for five categories of road surface hardness and five traffic categories.

The assessment of the hardness of the existing road surface may be made on the basis of judgement with the help of the definitions given in Table A 2.1. Alternatively a simple penetration probe test may be used to measure the hardness of the road surface. This test, which utilises a modified cone penetrometer, is described briefly in Overseas Road Note 3*.

In selecting the nominal size of chipping for double surface dressings the size of chippings for the first layer should be selected on the basis of the hardness of the existing surface and the traffic category as indicated in Table 4.5. The nominal size of chipping selected for the second layer should then be about halt the nominal size of that of the first layer to promote good interlock between the layers, e. g. a. 19 mm first layer chipping should be followed by a 10 mm second layer chipping, or a 13 mm first layer chipping should be followed by a 10 mm or 6 mm second layer chipping .

In the case of a hard existing surface where very little embedment of the first layer of chippings is possible such as a newly constructed cement stabilized road base or a dense crushed rock base, a 'pad coat' of 6 mm chippings should be applied first followed by 10 mm or 13 mm chippings in the second layer. The first layer of small chippings will adhere well to the hard surface and will provide a 'key' for the larger stone of the second dressing

Table A 2.1. Categories of Road Surface Hardness

Category of Surface	**Penetration@ at 30° C (mm)**	**Definition**
Very hard	0-2	Surfaces, such as concrete, or very lean bituminous structures with dry stony surface into which negligible penetration of chipping will occur even under the heaviest traffic
Hard	2-5	Surfaces into which chippings will penetrate only slightly under heavy traffic.
Normal	5-8	Surface into which chippings will penetrate moderately under medium and heavy traffic
Soft	8-12	Surfaces into which chippings will penetrate considerably under medium and heavy trffic
Very soft	>12	Surfaces, usually rich in binder, into which even large chippings will be submerged under heavy traffic.

@see Overseas Road Note 3, Appendix 4

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* Overseas Road Note 3, "A guide to surface dressing in tropical and sub-tropical countries", by the Transport and Road Research Laboratory, UK. Reference should be made to this document for additional detail.

DETERMINING THE RATE OF SPREAD OF BINDER

Having selected the nominal size of chippings and the type of binder to be used, the next step in the design of a surface dressing is to determine the rate of spread of the binder

The method of surface dressing design put forward by Jackson (*) is suitable for general application. The Jackson design method requires the determination of the Average Least Dimension (ALD) of the chippings that are to be used for the surface dressing. An overall weighting factor is then determined by adding together four factors that represent the level of traffic, the condition of the existing road surface, the climate and the type of chippings.

Using the ALD and the overall weighting factor a design chart is then used to obtain the required rate of spread of the binder and the approximate rate of application of the chippings.

Determining the average least dimension of the chippings

The Average Least Dimension (ALD) of chippings is a function of both the average size of the chippings, as determined by normal square mesh sieves, and the degree of flakiness. The ALD may be determined in two ways:-

Method-A

A grading analysis is performed on a representative sample of the chippings. The sieve size through which 50 per cent of the chippings pass is determined (known as the median size'). The flakiness index is then determined in accordance with IS:2386(Part I) and the ALD is read off from the nomo-graph shown in Fig A 3.1.

Method-B

The least dimension of a sample of approximately 200 representative chippings is measured manually. The chippings are obtained by careful sample sub-division in accordance with British Standard 812. The mean value of the measurements is then calculated.

Determining the overall weighting factor

Factors appropriate to the site of the surface dressing are selected from the following four tables on the basis of the volume of traffic, the condition of the road surface, the climate and the type of chippings that will be used. These four factors are then added together to give the overall weighting factor

TRAFFIC

	vehicles/lane/day	Factor
Very light	0-50	+3
Light	50-250	+1
Medium	250-500	0
medium-heavy	500-1500	-1
Heavy	1500-3000	-3
very heavy	3000+	-5

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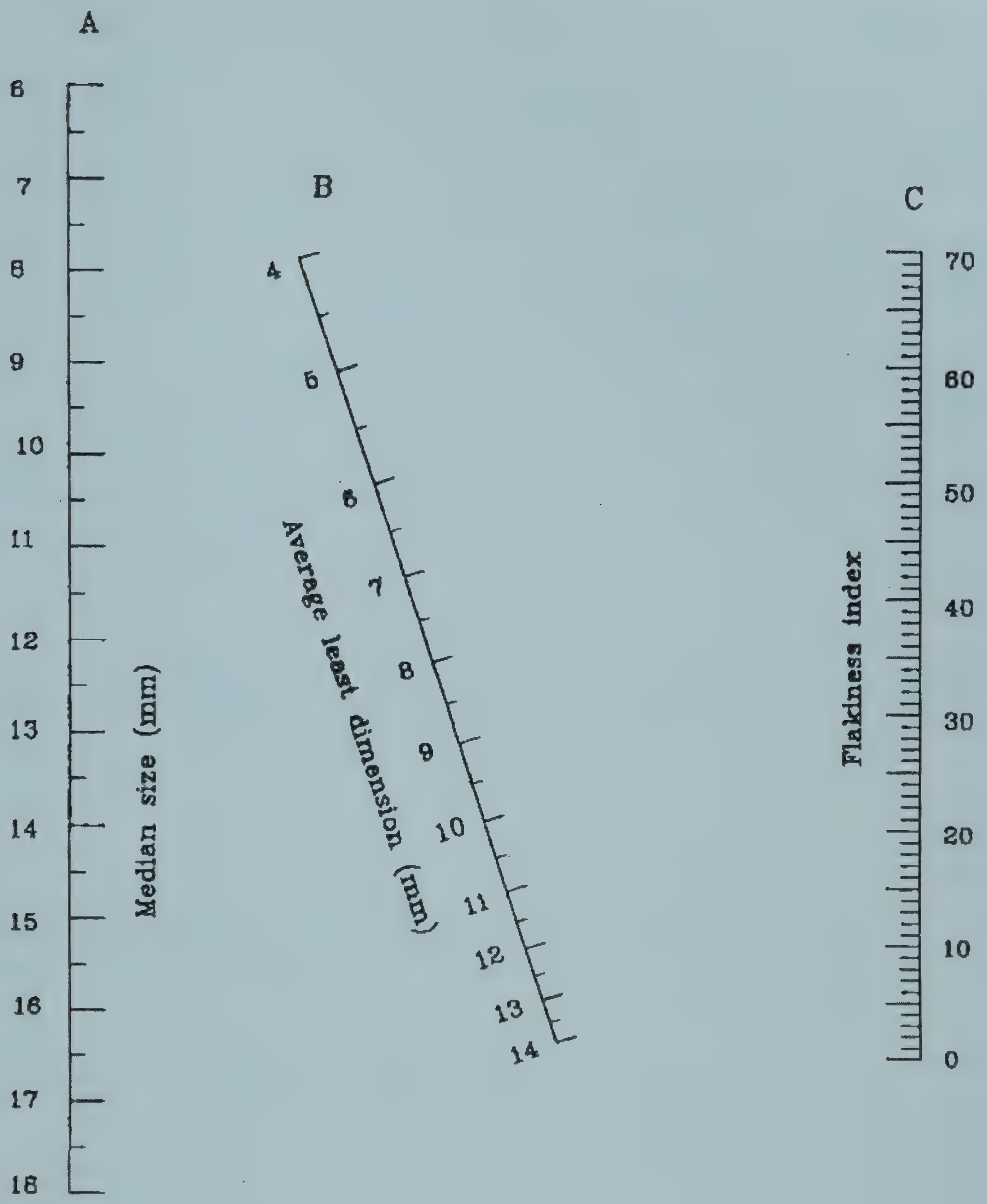
* See reference 11 in Overseas Road Note 3.


A
B
C
Median size (mm)
6
7
8
9
10
11
12
13
14
15
16
17
18
Average least dimension (mm)
4
5
6
7
8
9
10
11
12
13
14
Flakiness index
70
60
50
40
30
20
10
0

Method: Join A to C
Read average least dimension on B

Fig. A 3.1. Determination of Average Least Dimension

EXISTING SURFACE

	Factor
Untreated or primed base	+6
Very lean bituminous	+4
Lean bituminous	0
Average bituminous	-1
Very rich bituminous	-3

CLIMATE CONDITIONS

	Factor
Factor Wet and cold	+2
Tropical (wet and hot)	+1
Temperate	0
Semi-arid (hot and dry)	-1
Arid (very dry and very hot)	-2

TYPE OF CHIPPINGS

	Factor
Round/dusty	+2
Cubical	0
Flaky	-2
Pre-coated	-2

For example if flaky chippings (factor -2) are to be used at a road site carrying medium to heavy traffic (factor -1) and which has a very rich bituminous surface (factor-3) in a wet tropical climate (factor +1) the overall weighting factor is:

$$-2 -1 -3 +1 = -5$$

Using the design chart

Having determined the ALD of the chippings and the overall weighting factor, the intercept between the factor line and the appropriate ALD line is located in the design chart shown in Fig. A 3.2. The rate of spread of the binder is then read off directly at the bottom of the chart.

To determine the approximate application rate of the chippings the intersection of the ALD line with the line AB is located and the chipping application rate, which includes a 10 per cent allowance for whip off, is read off at the top of the chart. The chipping application rate should be regarded as a rough guide only. It is useful in calculating the gross quantity of chippings that is required for a surface dressing but the precise application rate will be determined by observing on site whether any exposed binder remains after spreading the chippings, indicating too low a rate of application of chippings, or whether more than one layer of chippings is spread, indicating too high an application rate. Best results are obtained when the chippings are tightly packed together, one layer thick. To achieve this a slight excess of chippings must be applied initially: some will be moved by the traffic and will tend to fill small areas where there are insufficient chippings. Too great an excess of chippings will increase the risk of whip-off and windscreen damage.

Another method of estimating the approximate application rate of the chippings is to spread a single layer of chippings taken from the stockpile on a tray of known area. The chippings are then weighed, the process repeated ten times with fresh chippings, and the mean value calculated. An additional ten per cent is allowed for whip off. Storage and handling losses must also be allowed for when stockpiling chippings.

The Jackson method of determining the rate of spread of binder requires the estimation of traffic in terms of numbers of vehicles only. If the proportion of commercial vehicles in the traffic stream is high the traffic factor selected should be that of the next higher category of traffic than that indicated by the simple volume count.

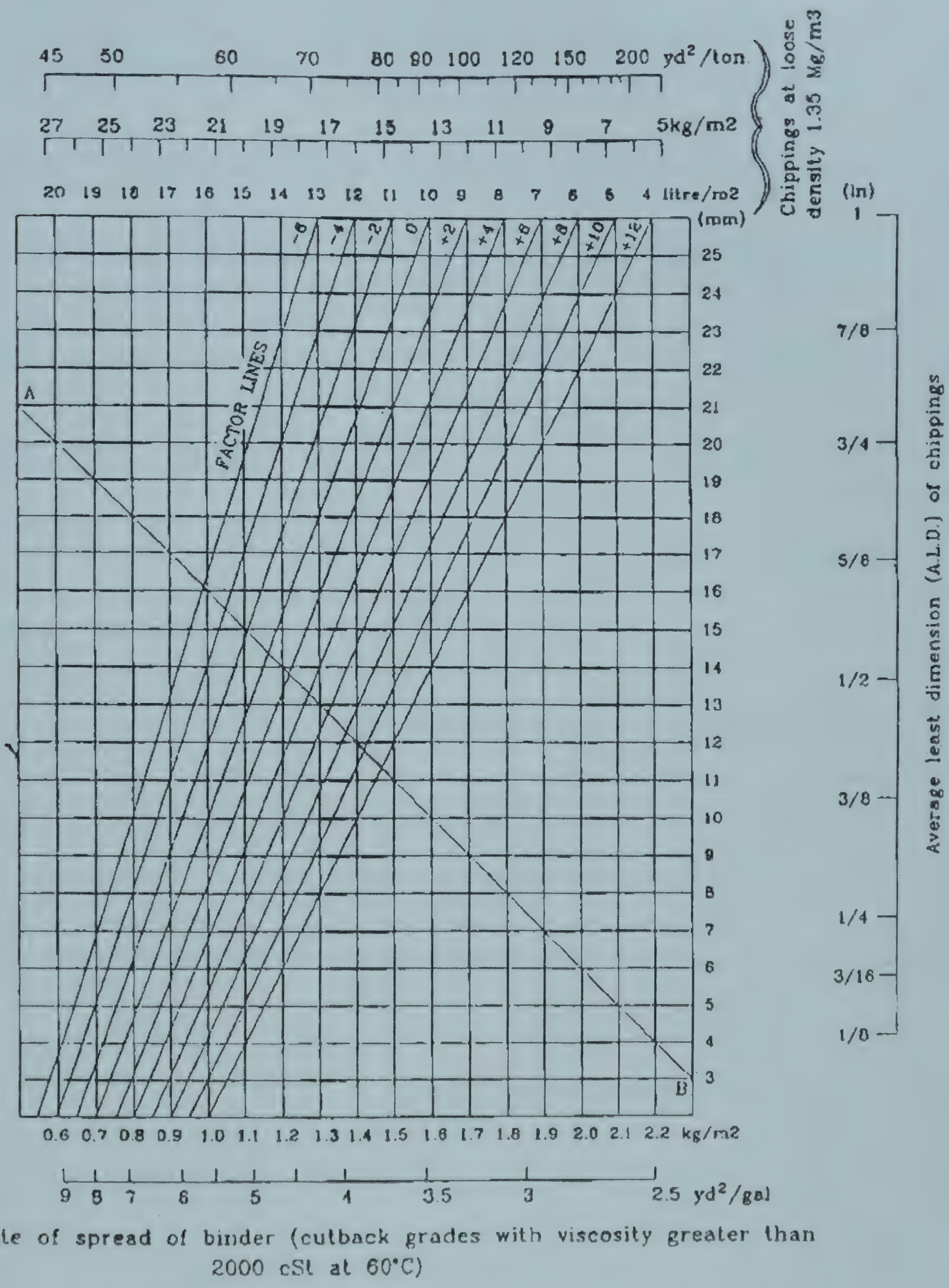


Fig. A 3.2, Surface Dressing Design Chart

* 1. For slow traffic or climbing grades steeper than 3 per cent, reduce the rate of spread of binder by 10 per cent.

*2. For fast traffic or downgrades steeper than 3 per cent increase the rate of spread of binder by 10 to 20 per cent.

Research has indicated that best results will be obtained if the rate of spread of binder given by the design chart is adjusted to take account of traffic speed and road gradient as follows:-

1. For slow traffic or climbing grades with gradients steeper than 3 per cent, the rate of spread of binder should be reduced by 10 per cent.
2. For fast traffic or downgrades steeper than 3 per cent the rate of spread of binder should be increased by 10 to 20 per cent.

If the existing surface of the road is rough, it should be rated as 'very lean bituminous' even if its overall colour is dark with bitumen. This rating allows for the amount of binder which is required to fill the surface voids and which is hence not available to contribute to the binder film that retains the chippings. Similarly, when determining the rate of spread of binder for the second layer of a double surface dressing, the first layer should also be rated 'very lean bituminous'.

Finally the actual rate of spread of binder has to be modified to allow for the type of binder used. The following modifications are appropriate:-

1. Penetration grade binder:- decrease the rate of spread by 10 per cent.
2. Cutback binder:- for cutbacks with a viscosity greater than 2000 centistokes at 60°C, no modification is required. (In the rare cases when cutbacks with lower viscosity are used the rate of spread may need to be increased by 10 per cent).
3. Emulsion binder:- multiply the rate of spread given in the chart by

$$\frac{90}{\text{bitumen content of the emulsion (per cent)}}$$

No design method will produce a satisfactory result if the other essential requirements of the surface dressing process are not met. It is particularly important that the binder viscosity is appropriate for the prevailing road temperature, that efficient spraying equipment is used, and that adequate site preparation and job supervision is undertaken.

THE IMMERSION TRAY TEST FOR DETERMINING THE CONCENTRATION OF ADHESIVE AGENT REQUIRED

In this test a tin lid approximately 135 mm diameter is covered with 15-20 gr of binder giving a film some 1.5 mm thick. When this has cooled to the test temperature* it is immersed in water also at test temperature to a depth of about 25 mm. Nominal 14 mm chipping are then applied by hand and lightly pressed in. At least six pieces of the aggregate are used. The chippings are left for 10 minutes and are then carefully removed from the binder film: the percentage of binder retained on the chippings is assessed visually.

When testing an adhesion agent, a known quantity of agent is added to the binder and thoroughly stirred to ensure good dispersion. The procedure is then repeated as outlined above. The test is repeated with varying concentrations of agent in the binder until the minimum concentration required to give satisfactory results has been found. The concentration normally falls in the range 0.5 to 2.5 per cent by mass of agent.

The mass of agent may be considered satisfactory for use on the road if, in the test, when the chippings are lifted from the binder film the faces which have been in contact with the film are all 90-100 per cent coated with binder.

Note. Vialit Test -

A new test, "Determination of binder-aggregate adhesivity by the vialit plate shock test method", Draft European Standard prEN00227206, enables an assessment to be made of overall binder-aggregate adhesivity at close to site conditions for a surface dressing. This test can be used to determine the need for and effectiveness of special treatments such as the use of adhesion agents. The gradual adoption of this test should lead to phasing out of the current highly subjective water immersion tests.

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* The temperature of water and tray of binder in the above test should be the expected temperature of the road surface during the treatment. Where it is desired to compare the behaviour of different agents with a given stone and binder it is suggested that 20°C should be used as the test temperature.

REFUSAL DENSITY DESIGN

1. Introduction

Under severe loading conditions asphalt mixtures must be expected to experience significant secondary compaction in the wheelpaths. Severe conditions will consist of a combination of two or more of the following, as determined by the Contract or by the Engineer :

- High maximum temperatures
- Very heavy axle loads
- Very channeled traffic
- Stopping or slow moving heavy vehicles

Failure by plastic deformation in continuously graded mixtures occurs very rapidly once the air voids are below 3 per cent, therefore the aim of refusal density design is to ensure that at refusal there is still at least 3 per cent voids in the mixture.

For sites which do not fall into the severe category, the method may be used to ensure that the maximum binder content for good`durability is obtained. This may be higher than the Marshall optimum but the requirements for resistance to deformation will be maintained. Where lower axle loads and higher vehicle speeds are involved, the minimum air voids at refusal can be reduced to 2 per cent.

This method, based on an extended form of the compaction procedure used in the Percentage Refusal Density (PRD) Test (BS 598 Part 104 (1989)), uses a vibrating hammer for compaction. The method is appropriate for sites which are subject to severe loading where research has shown that it is desirable to retain a minimum air voids of three per cent after secondary compaction by traffic, to minimise the risk of failure by plastic deformation. The method does not exactly reproduce the mode of compaction which occurs under heavy traffic, but the procedure is considered to be the most representative available.

2. Extended Vibrating Hammer Compaction

2.1. Laboratory design procedure : In the vibrating hammer method the samples are compacted in 152-153 mm diameter moulds to a thickness approximately the same as will be laid on the road. The BS 598 compaction procedure for the PRD test is repeated as necessary to achieve an 'absolute' refusal density. The electric vibrating hammer should have a power consumption of 750 watts or more and operate at a frequency of 20 to 50 Hz. Two tamping feet are used, one with a diameter of 102 mm and the other of 146 mm. Samples should be mixed so that they can be compacted immediately afterwards at an initial temperature of 140 ± 5°C for 80/100 penetration grade bitumen or 145 ± 5°C for 60/70 penetration grade bitumen.

The moulds and tamping feet must be pre-heated in an oven before starting the test. Cooling of the sample by as much as 15 to 20°C during compaction should not prevent achievement of the correct refusal density. The small tamping foot is used for most of the compaction sequence. The hammer must be held firmly in a vertical position and moved from position to position in the prescribed order, i.e., using the points of a compass. To identify the position, the order should be N,S,W,E,NW,SE,SW,NE or equivalent. At each point, compaction should continue for between 2 and 10 seconds, the limiting factor being that material should not be allowed to 'push up' around the compaction foot. The compaction sequence is continued until a total of 2 minutes ± 5 seconds of compaction time has been reached. The large tamping foot is then used to smooth the surface of the sample.

A spare base-plate, previously heated in the oven, is placed on top of the mould which is then turned over. The sample is driven to the new base plate with the hammer and large tamping foot. The compaction sequence is then repeated. The free base plate should be returned to the oven between compaction cycles.

This is the standard PRD compaction procedure but to ensure that the refusal density is reached, it may be necessary to repeat this procedure a second time. It is suggested that trial mixes with a bitumen content which corresponds to approximately 6 per cent air voids in the Marshall test, are used to:

(i) determine the mass of material required to give a compacted thickness of approximately the same thickness as for the layer on the road;

(ii) determine the number of compaction cycles which will ensure that absolute refusal density is achieved.

After these tests have been completed, samples are made with bitumen contents starting at the Marshall optimum and decreasing in 0.5 per cent steps until the bitumen content at which 3 per cent air voids is retained at absolute refusal density can be determined.

2.2 Transfer of laboratory design to compaction trials : After the standard PRD compaction cycle, test samples of base course or road base which have been compacted from the loose state can be expected to have densities between 1.5 and 3 percent lower than for the same material compacted in the road but cored out and subjected to the PRD test. This is an indication of the effect of the different compaction regime and is caused by a different resultant orientation of particles. The differences between the densities for laboratory and field samples after refusal compaction should be measured to confirm whether this difference occurs.

A minimum of three trial lengths should be constructed with bitumen contents at the laboratory optimum for refusal density (3 per cent air voids) and at 0.5 per cent above and 0.5 per cent below the optimum. These trials should be used to:

(i) determine the rolling pattern required to obtain a satisfactory density;

(ii) establish that the mix has satisfactory workability to allow a minimum of 93 per cent of PRD (standard compaction (BS598:1989)) to be achieved after rolling;

(iii) obtain cores so that the maximum binder content which allows at least 3 per cent air voids to be retained at refusal density can be confirmed.

For a given aggregate and grading, cores cut from the compacted layer can be assumed to give a constant value of voids in the mineral aggregate (VMA) at the refusal density, irrespective of bitumen content. This will allow a suitable binder content to be chosen to give a minimum of 3 per cent air voids at refusal density.

A minimum of 93 per cent and a mean value of 95 per cent of the standard PRD density is recommended as the Specification for density on completion of compaction of the layer. From these trials and the results of laboratory tests, it is then possible to establish a job mix formula. This initial procedure is time consuming, but is justified by the long term savings in extended pavement service life that can be obtained. After this initial work, subsequent compliance testing based on analysis of mixture composition and refusal density should be quick, especially if field compaction can be monitored with a nuclear density gauge.

It is essential to provide a surface dressing for the type of base course mixtures which are best suited to these severe conditions. This protects the mixture from severe age hardening during the period when secondary compaction occurs in the wheelpaths, and also protects those areas which will not be trafficked and are likely to retain air voids above 5 per cent.

3. Possible Problems with the Test Procedures

Vibratory compaction may cause breakdown of aggregate particles. If this occurs to a significant extent then the test is unlikely to be valid.

It is important to note that the different particle orientation produced by this compaction method, in comparison with that produced by roller compaction, limits the use of samples prepared in these tests to that of determining air voids at refusal. Care is required if samples prepared in this way are to be used for testing of mechanical properties.

4. References

(i) British Standard Institution, "Sampling and examination of bituminous mixtures for roads and other paved areas. Method of test for the determination of density and compaction", British Standard BS 598: Part 104, 1989.

(ii) Overseas Road Note 31, "A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical countries", Transport Research Laboratory, 1993.

THE BINDER DRAINAGE TEST

1. Scope

This test determines the target binder content for stone mastic asphalt, to prevent excessive bindr drainage occurring during manufacture, transportation and laying.

2. Summary of Method

The quantity of binder lost through drainage, after a specified time at the maximum mixing temperature should be measured in duplicate for mixes with the same aggregate contents but with different binder contents. The target binder content should be defined as the value 0.3 per cent less than that at which 0.3 per cent binder drainage occurs, sec also Clause 7 below.

3. Apparatus

The apparatus should consist of:

(i) Balance of not less than 2 kg capacity, accurate to 0.1 g.

(ii) Oven, with fan-assisted air circulation, fitted with thermostatic control to maintain the temperature to ± 3°C in the range of 80°C to 200°C and having sufficient internal volume to accommodate 10 drainage baskets and trays.

(iii) Mechanical mixing unit of not more than 8 litres capacity, capable of combining 1500 g of aggregate, filler and binder speedily and thoroughly, without loss, as described in BS 598: Part 107

(iv) Whisk, as described in BS 598: Part 107.

(v) Drainage baskets, ten in number, constructed from perforated metal with 3.1 ± 0.1 mm diameter holes and with 38 ± 3 per cent open area, on sides and base to form 100 ± 2 mm cubes, with feet, at each corner of the base, of 3 ± 0.5 mm diameter and 5 ± 1 mm height.

(vi) Spatula, with a blade approximately 150 mm long by 25 mm wide.

(vii) Metal trays, approximately 150 mm square and 10 mm deep, ten in number.

(viii) Metal tins, approximately 150 mm by 150mm by 150 mm, eleven in number.

(ix) Aluminium foil, of thickness 0.015 ± 0.005 mm.

4. Materials

Sufficient aggregates and binder to manufacture at least 20 kg of stone mastic asphalt. The aggregates should be dried and graded in the fraction appropriate to the specified grading.

5. Procedure

The procedure should be as follows:

(i) The test should be carried out at the maximum mixing temperature at which the binder or modified binder viscosity is 0.5 Pas. In the absence of viscosity data, the test temperature should be as given in Table A 6.1 or as stated in the relevant Specification agreed by the Engineer.

(ii) Weigh eleven batches of 1.1 kg of combined aggregate, in the proportions for each fraction, to the nearest 1 g to give a gracing complying with the mid-point of the specified grading limits. Place each batch in a separate tin.

Table A 6.1. Drainage Test Temperature

Binder	Test Temperature (°C)
200 pen bitumen	140 ± 3
200 pen bitumen plus 5 per cent natural rubber	150 ± 3
100 pen bitumen	155 ± 3
100 pen bitumen 5 per cent natural rubber	160 ± 3
60 /70 pen bitumen	170 ± 3
50/60 pen bitumen	170 ± 3

A typical diagram of mortar drained is shown in Fig. A6.1

(iii) Pre-heat the oven to the maximum mixing temperature and place the tins with aggregates in the oven for at least 3 ± 1 hours prior to use.

(iv) Pre-heat, stir and sub-divide the binder by the method stated in BS 598: Part 107.

(v) Wrap each tray with aluminum foil. Weigh each tray with foil to the nearest 0.1 g (W_1)

(vi) Per-heat the mixing unit to the maximum mixing temperature for at least 1.5 ± 0.5 hour prior to use.

(vii) Transfer a 1.1 kg batch of aggregate to the mixing bowl.

(viii) When stabilising additive or natural rubber powder is to be used, add the required quantity to the mixing bowl. Fit the mixing bowl to the mixer and fit the whisk. Dry mix for 30 ± 3s before adding the bitumen.

(ix) Stir the heated binder in its container and weigh by difference the required amount of binder to the nearest 0.5 g, into the mixing bowl to give a binder content (in per cent by mass of total mixture approximately 1% less than the expected optimum.

(x) When natural rubber latex is to be used; after adding the bitumen fit the mixing bowl to the mixer and fit the whisk. Mix the aggregates and bitumen for 60 ± 6s. Stir the latex well and add the required quantity evenly over the mix

(xi) Fit the mixing bowl to the mixer; fit the whisk and mix for another 60 ± 6s. Using the spatula scrape around the top of the bowl and whisk and transfer the scraped material into the mix Continue mixing for a further 60 ± 6s.

(xii) Discard the first mix.

(xiii) Repeat steps (vii) To (xi)

(xiv) Transfer the material to a basket, ensuring that the mixer bowl and whisk are scraped thoroughly using the spatula Carry out this possible as rapidly as possible to minimise heat losses.

(xv) Place the basket with the mix on a pre-wrapped tray in the oven at the maximum mixing temperature for between 3 hours and 3.25 hours.

(xvi) Remove the basket and tray from the oven . Remove the basket from the drainage tray when has cooled sufficiently, weigh the tray and aluminium foil to the nearest foil to the nearest 0.1 g (W^2)

(xvii) After placing the first mix in the oven, repeat the procedure in steps (xiii) to (xvi) for a duplicate sample to the same binder content

(xviii) Repeat the procedure in steps (xiii) and (xvii) four times, but progressively increasing the binder content in step (ix) in 0.5 per cent increments (in per cent by mass of total mixture).

(xix) When a modifier other than natural rubber is used, the procedure for incorporating the modifier should be according to the manufacturers' instructions.

6. Calculations

Calculate the mortar drained from each sample dm (in %) from the equation:

$$d_m = 100 \times \frac{W_2 - W_1}{(1100 + B + X)}$$

Where

W_1 is the initial mass of the tray with foil (g)
W_2 is the final mass of the tray with foil and drained mortar (g)
B is the initial mass of binder in the mix (g)
X is the initial mass of fibres in the mix (g)

If, for any pair of mixes at the same binder content, the difference in the mortar drained exceeds 0.5 per cent, the procedure in Clause 5 and calculation in Clause 6, for the pair of mixes at the same binder content, should be repeated.

For each binder content, calculate the mortar drained D_M in (per cent) as the mean of the mortar drained from the pair of samples. Calculate the mortar drained for each binder content and plot the values, against the initial mixed binder content. Draw a smooth curve through the plotted values, values, as in Fig. A 6.1.

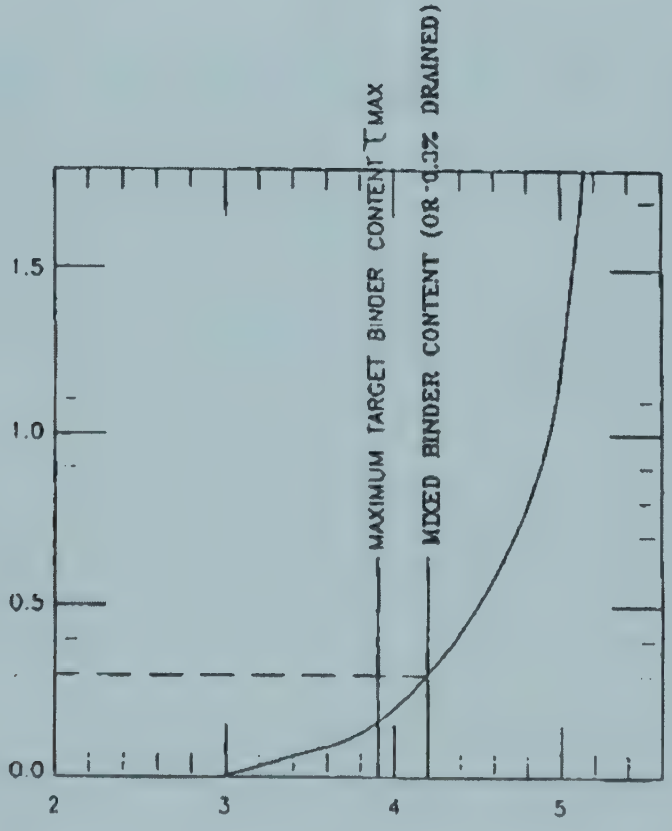


Fig. A 6.1 Typical Diagram of Mortar Drained

7. Determination Maximum Target Binder Content

From Fig. A 6.1, determine the mixed binder content (M_m) where the mortar drainage is 0.3 per cent. Calculate the maximum target binder Content $T_{max,m}$ (in %) from the equation:

$$T_{max,m} = M_m - O.3$$

8. References

1. British Standards Institution, "Method for determination of the maximum binder content of bituminous mixtures without excessive binder drainage" British Standard Draft for Development BS: DD 232, 1996.

GUIDELINES FOR EVALUATION OF MIXTURE VOLUMETRICS

1. Evaluation of VMA Curve

In many cases, the most difficult mix design property to achieve is a minimum amount of voids in the mineral aggregate. The goal is to furnish enough space for the bitumen so it can provide adequate adhesion to bind the aggregate particles, but without bleeding when temperatures rise and the binder expands. Normally, the VMA curve exhibits a flattened U-shape, decreasing to a minimum value and then increasing with increasing binder content, shown in Fig. A 7.1 (a).

This dependency of VMA on on binder content appears to be a contradiction to the definition. One might expect the VMA to remain constant with varying binder content, thinking that the air voids would simply be displaced by binder. In reality, the total volume changes across the range of binder contents; the assumption of a constant unit volume is not accurate. With the increase in binder, the mix actually becomes more workable and compacts more easily, meaning more weight can be compressed into less volume. Therefore, up to a point, the bulk density of the mix increased and the VMA decreases.

At some point as the binder content increases (the bottom of the U-shaped curve) the VMA begins to increase because relatively more dense material (aggregate) is displaced and pushed apart by the less dense material (binder). It is recommended that binder contents on the "wet" or right-hand increasing side of this VMA curve be avoided, even if the minimum air void and VMA criteria are met. Design binder contents in this range have a tendency to bleed and/or exhibit plastic flow when placed in the field. Any amount of additional compaction from traffic leads to inadequate from for binder expansion, loss of aggregate-to-aggregate contact, and eventually, rutting and shoving in high traffic areas. Ideally, the design binder content should be selected slightly to the left of the low point of the VMA curve, provided none of the other mixture criteria are violated.

In some mixtures, the bottom of the U-shaped VMA curve is very flat, meaning that the compacted mixture is not as sensitive to binder content in this range as some other factors. In the normal range of binder contents, compatibility is influenced more by aggregated properties. However, at some point the quantity of binder will become critical to the behaviour of the mix and the effect of binder will dominate as the VMA increases drastically.

When the bottom of the U-shaped VMA curve falls below the minimum criteria level required for the nominal mineral maximum aggregate size of the mix [Fig. A 7.1 (b)], this is an indication that changes to the job-mix formula are necessary. Specifically, the aggregate grading should be modified to provide additional VMA. The design binder content should not be selected at the extremes of the acceptable range even though the minimum criteria are met. On the right-hand side, the mix would be too dry, prone to segregation, and would probably be too high in air voids. On the right-hand side, the mix would be expected to rut.

If the minimum VMA criteria are completely violated over the entire binder content range [curve is completely below minimum, Fig. A 7.1 (c)], a significant redesign and/or change in material sources is warranted.

2. Effect of Compaction Level

At the same binder content, both air voids (Va) and voids in the mineral aggregate (VMA) decrease with higher compactive effort. The three levels of compaction of the Marshall mix procedure can be used to illustrate the consequences of this fact. As shown in Fig. A 7.2 (a) , not only do the magnitudes of the values change but the

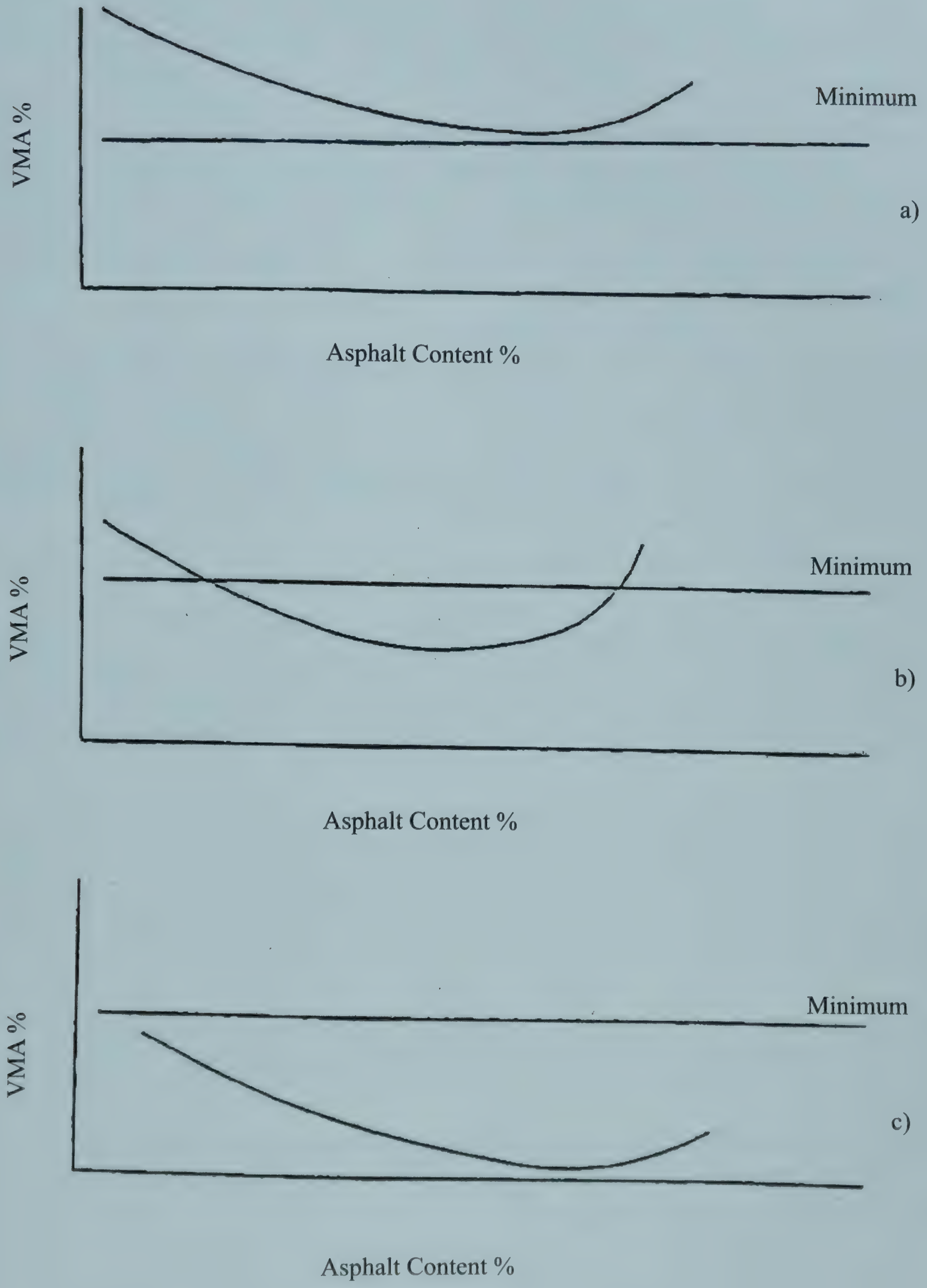


Fig. A 7.1 Relationship Between VMA and Specification Limit

binder content value at the minimum VMA shifts. If a mix is designed slightly to the left of minimum VMA at a compaction level of 50 blows and the pavement actually endures heavier traffic than expected (closer to 75-blow design level); then, the same binder content now plots on the right-hand or "wet" side of the minimum VMA point of a mix designed using 75 blow compaction. Ultimately, a mix susceptible to rutting is the result.

This scenario can also work in the opposite direction. If a mix, designed at a compaction level of 75 blows as shown in Fig. A 7.2(b), is placed in a pavement with much lower volumes of traffic, then the final percentage of air voids (Va) will be considerably higher than planned. This condition could lead to a more open, permeable mix allowing air and water to pass through easily. The consequence of this situation is a mix that hardens prematurely, becomes brittle and cracks at an early age or the aggregate ravels out of the mix because of the loss of binder adhesion. This condition may also lead to stripping.

For this reason, it is important that the compactive effort used to simulate the design traffic expected in the pavement be selected accordingly in the laboratory. Also, the mixture must be constructed with appropriate compactiori equipment in the field to produce adequate initial density regardless of climate conditions.

It is also important to note that the VMA criteria do not change based on the level of compaction. The reasoning for having sufficient VMA (providing space for the binder and air voids) is consistent regardless of the traffic level for ,which the mixture is being designed.

3. Effect of Air Voids

It should be emphasized that the design range of air voids (3 to 5 per cent) is the level desired after several years of traffic. This goal does not vary with traffic; the laboratory compactive effort is supposed to be selected for the expected traffic. This design air void range will normally be achieved if the mix is designed at the correct compactive effort and the percent air voids after construction is about 8 per cent. Some consolidation with traffic is expected and desired.

The consequence of a change in any factor or any detour in the procedure that offsets the total process will be a loss of performance or service life. It has been shown that mixtures that ultimately consolidate to less than three percent air voids can be expected to rut and shove if placed in heavy traffic locations. Several factors may contribute to this occurrence, such as an arbitrary or accidental increase in binder content at the mixing facility or an increase of ultra-fine particles passing the 0.075 mm (No. 200) sieve beyond that used in the laboratory, which will act as an binder extender.

Similarly, problems can occur if the final air void content is above five per cent or if the pavement is constructed with over eight per cent voids initially. Brittleness, premature cracking, ravelling, and stripping are also possible under these conditions.

The overall objective is to limit adjustments of the design binder content to less than 0.5 per cent air voids from the median of the design criteria (four per cent), especially on the low side of the range, and to verify that the plant mix closely resembles the laboratory mix.

4. Effect of Voids Filled with Binder

Although VFB, VMA and Va are all interrelated and only two of the values are necessary to solve for the other, including the VFB criteria helps prevent the design of mixes with marginally-acceptable VMA. The main effect of the VFB criteria is to limit maximum levels of VMA, and, subsequently, maximum levels of binder content.

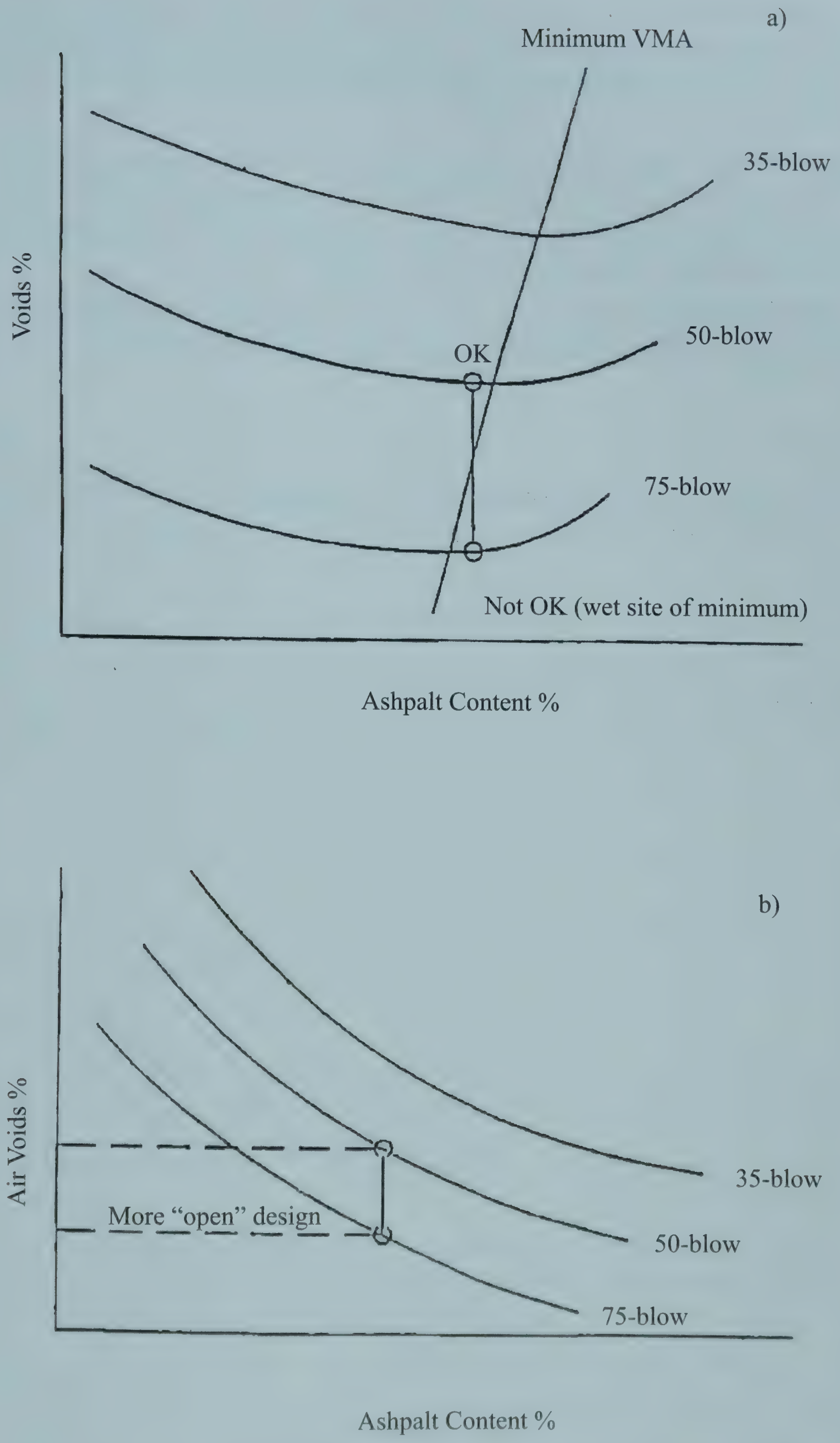


Fig. A 7.2. Effect of Marshall Compactive Effort on VMA and Air Voids

VFB also restricts the allowable air voids content for mixes that are near the minimum VMA criteria. Mixes designed for lower traffic volumes will not pass the VFB criteria with a relatively high per cent air voids (five per cent) even though the air void criteria range is met. The purpose is to avoid less durable mixes in light traffic situations.

Mixes designed for heavy traffic will not pass the VFB criteria with relatively low per cent air voids (less than 3.5 per cent) even though that amount of air voids is within the acceptable range. Because low air void content can be very critical in terms of permanent deformation (as discussed previously), the VFB criteria helps to avoid those mixes that would be susceptible to rutting in heavy traffic situations.

The VFB criteria provide an additional factor of safety in the design and construction process•in terms of performance. Since changes can occur between the design stage and actual construction, an increased margin for error is desirable.

References

[1] The Asphalt Institute, “Mix design methods for asphalt concrete and other hot mix types”, Asphalt Institute Manual Series No. 2 (MS-2), 6th Edition, 1995.

GUIDELINES FOR LABORATORY PREPARATION OF COMPACTED BITUMINOUS MIXTURES

1. Scope

This standard practice is used to prepare compacted bituminous mixture specimens in the laboratory such that they are simulative of newly constructed bituminous pavements. The practice includes a short-term ageing procedure for continuously-graded mixtures which is intended to simulate the amount of hardening which occurs during the construction process (i.e., the hardening of the bitumen which occurs during mixing, storage, transport and laydown).

2. Definitions

2.1. Ageing

Ageing refers to the hardening or embrittlement of the bitumen in bitumen-aggregate mixtures as a result of compositional changes in the bitumen due to many factors such as time, temperature, oxidation, steric hardening, ultraviolet radiation, etc.

2.2. Short-term ageing

Short-term ageing refers to the hardening or embrittlement of the bitumen which occurs during the construction of bituminous mixtures. Hardening of the bitumen during the construction process may be the result of one or more of the following: mixing the bitumen and aggregate; silo storage of the mixture; transport of the mixture and/or lay down of the mixture.

3. Apparatus

3.1. Oven

Oven:forced-draft oven, which is thermostatically controlled and capable of being set to maintain any desired temperature from room temperature to 260°C with an accuracy of ± 1°C, or less.

3.2. Mixing apparatus

Any type of mechanical mixer which: (1) can be maintained at the required mixing temperature; (2) will provide a well coated, homogeneous mixture of the required amount of bituminous mixture in the allowable time, and; (3) allows essentially all of the mixture to be recovered.

3.3. Compactor

Compactor - any type of mechanical compactor which can compact the mixture to the desired density without causing damage to the aggregate. Suitable compactors include the Marshall hammer, Kango hammers, kneading compactors, rolling wheel compactors or gyratory compactors.

3.4. Digital thermometer

Digital thermometer capable of measuring temperatures from room temperature to 260°C and having an accuracy of ± 1°C or less.

3.5. Metal oven pans

Metal oven pans of sufficient size to heat the required amount of aggregate for each mixture.

3.6. Metal oven pans

Metal oven pans of sufficient size to receive as well as to heat the uncompacted bituminous mixture. The size of the pan should have an area and depth such that the mixture can be spread to a constant depth of 20 to 40 mm.

3.7. Metal spatula or spoon

Metal spatula or spoon of sufficient size to allow rapid and thorough mixing of the uncompacted mixture.

3.8. Oven gloves

4. Sampling

4.1. Aggregate should be sampled in accordance with BS:812: Part 102: 1989.

4.2. Bitumen should be sampled in accordance with BS:3690: Part 1: 1989.

5. Preparation

The aggregate should be graded in accordance with the mixture design or recipe Specification for the mixture. The amount of aggregate should be of sufficient size to obtain a mixture specimen of the desired size.

Obtain a sufficient quantity of bitumen such that the desired bitumen content can be mixed with the aggregate.

The desired mixing temperature (±2°C) should be obtained from the Bitumen Test Data Chart (see Fig. A 8.1) and should correspond to a viscosity of 2 Poise (0.2 Pas.) based on the original (unaged) bitumen properties.

The desired compaction temperature should also be obtained from the Bitumen Test Data Chart and should correspond to a viscosity of 3 Poise (0.3 Pas.) ±2°C based on the original bitumen properties

6. Procedure

Preheat the aggregate for a minimum of 2 hours at the desired mixing temperature.

Preheat the bitumen to the desired mixing temperature.

NOTE: Bitumens held at the desired mixing temperature for more than two hours should be discarded.

Preheat the mixer to the desired mixing temperature.

Preheat the metal oven pans to 135 ± 3°C.

When the aggregate and bitumen are at the desired mixing temperature, place the aggregate in the mixer and dry mix it thoroughly.

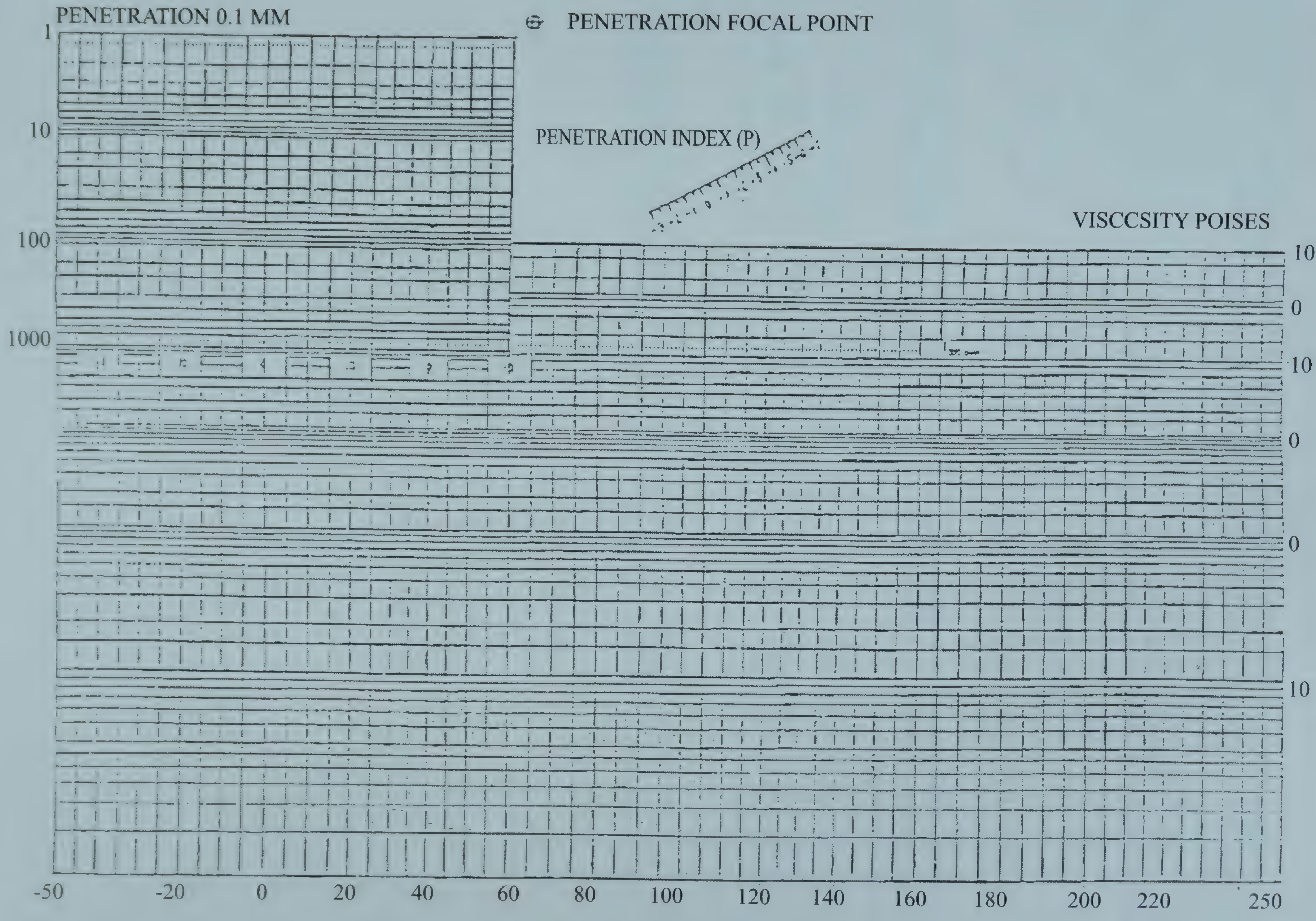


Fig. A 8.1. Bitumen Test Data Chart

Form a crater in the blended aggregate and add the required mass of bitumen.

Mix the bitumen and aggregate as quickly and thoroughly as possible to yield a mixture having a uniform distribution of bitumen throughout. For most mixtures 2 to 4 minutes, depending on mixer type, should be sufficient for thorough mixing. It is recommended that a standard mixing time (e.g., 4 minutes) be established for all mixtures.

For continuously-graded mixtures (e.g., dense bitumen macadams), place the mixture in a metal oven pan preheated to 135°C. Spread the mixture in the pan to an even depth approximately equal to the maximum. aggregate size (e.g., for a mixture with a maximum aggregate size of 20 mm, spread the mixture to a depth of approximately 20 mm). If the desired mixing temperature is greater than 135°C, allow the mixture to cool to 135°C, then place it a forced-draft oven at 135±3°C for 2 hours ±5 minutes. If the compaction temperature for the mixture is greater than I35°C, then cure the mixture at the compaction temperature for 2 hours ±5 minutes. Thoroughly stir the mixture using the spatula or spoon after 1 hour.

Ensure the temperature of the mixture is at the desired compaction temperature (i.e., allow the mixture to cool if the compaction temperature is less than 135°C) and compact the mixture to the desired density or in accordance with the established procedures for the particular compactor being used.

NOTE: The minirnIim time necessary should be used to heat the mixture if heating is required.

After compaction allow the compacted mixture specimen to cool to room temperature prior to extrusion or removal from the compaction mould.

Reference

[1] Brown, S.F., Gibb, J.M., Read, J.M. Scholz, T.V., and Cooper, K.E., "Design and testing of bituminous mixtures", Report submitted to DOT/EPSRC LINK Programme on Transport 'Infrastructure and Operations, January 1995.

ASSESSMENT OF ACCEPTABLE RANGES FOR VOIDS IN THE MINERAL AGGREGATE AND AIR VOIDS

Three key parameters are considered; void content (V_V), voids in mineral aggregate (VMA), and volumetric binder content (V_B). A range of potentially acceptable values has been established for each of these parameters, based on experience of mixtures with satisfactory performance. The ranges, presented below, are wide to reflect the variation in compatibility of aggregates from different sources.

Parameter	Permissible Range
V_v	3% - 8%
VMA	13% - 18%
V_B	$\geq$ 8%

More stringent tolerances for the above criteria have been developed, based on the assessment of achievable compaction for different aggregate types, using the mixture with a grading exponent of 0.5 and binder content of 3.5 per cent compacted to 100 PRD as the datum for volumetric proportions. The air void content of this mixture is deemed to reflect the compatibility of the aggregate and may be used to select a chart showing appropriate volumetric criteria. In each of these charts (Figs. A 9.1, A 9.2 and A 9.3) there is an area defined by ranges of void content and VMA, and with a cut-off for binder volume of 8 per cent. These values are based on experience, practical considerations and volumetric proportions at 100 PRD. The measured volumetric proportions are plotted on the appropriate chart, and those which fall outside the defined area should be rejected. Borderline cases may be retained.

Reference

[1] Brown, S.F., Gibb, 3.M., Read, J.M. Scholz, T.V. and Cooper, K.E., "Design and testing of bituminous mixtures", Report submitted to DOT/EPSRC LINK Programme on Transport Infrastructure and Operations, January 1995.

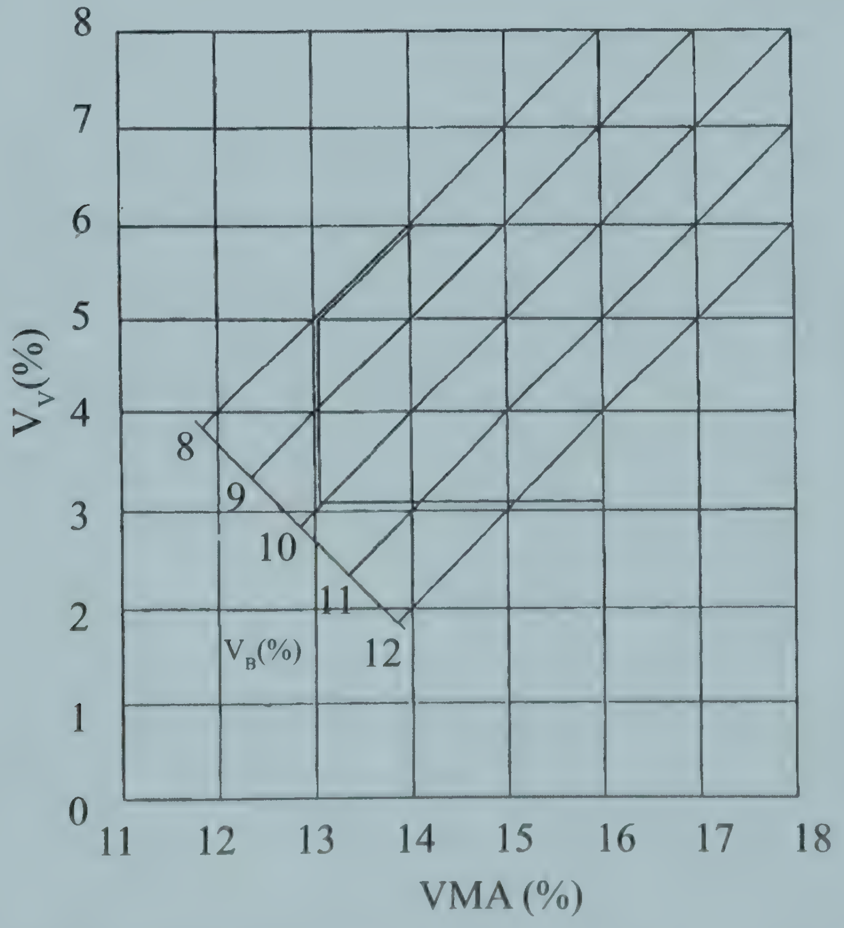


Fig. A 9.1. Volumetric Criteria Chart (1 per cent Voids at 100 PRD)

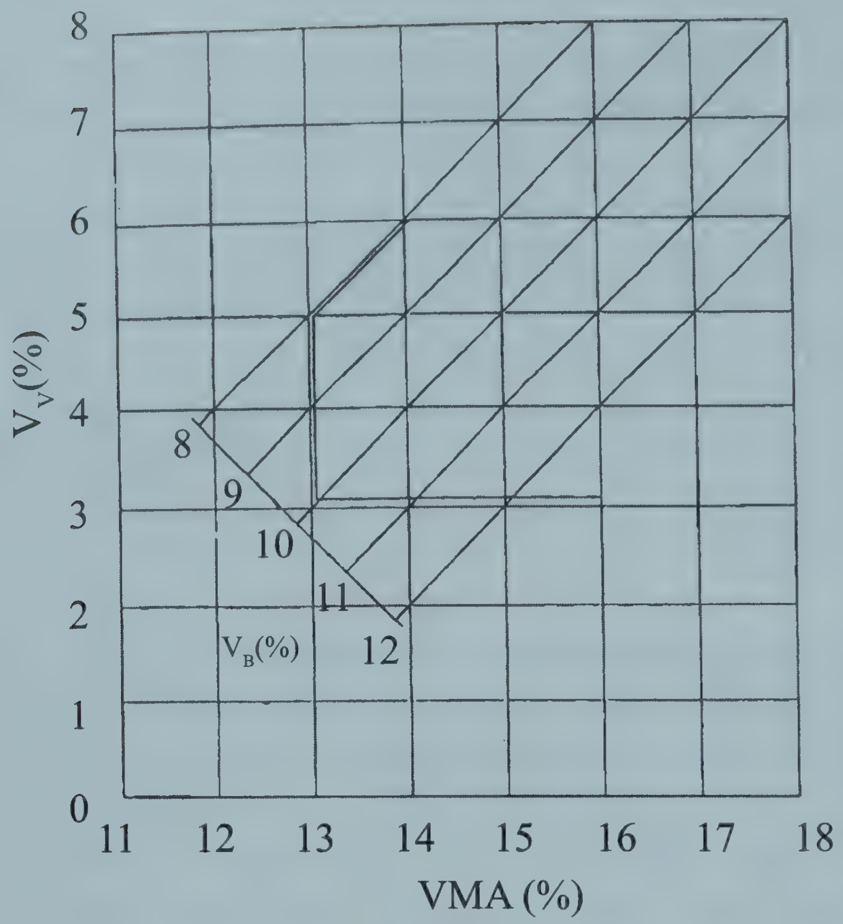


Fig. A 9.2. Volumetric Criteria Chart (2 per cent Voids at 100 PRD)

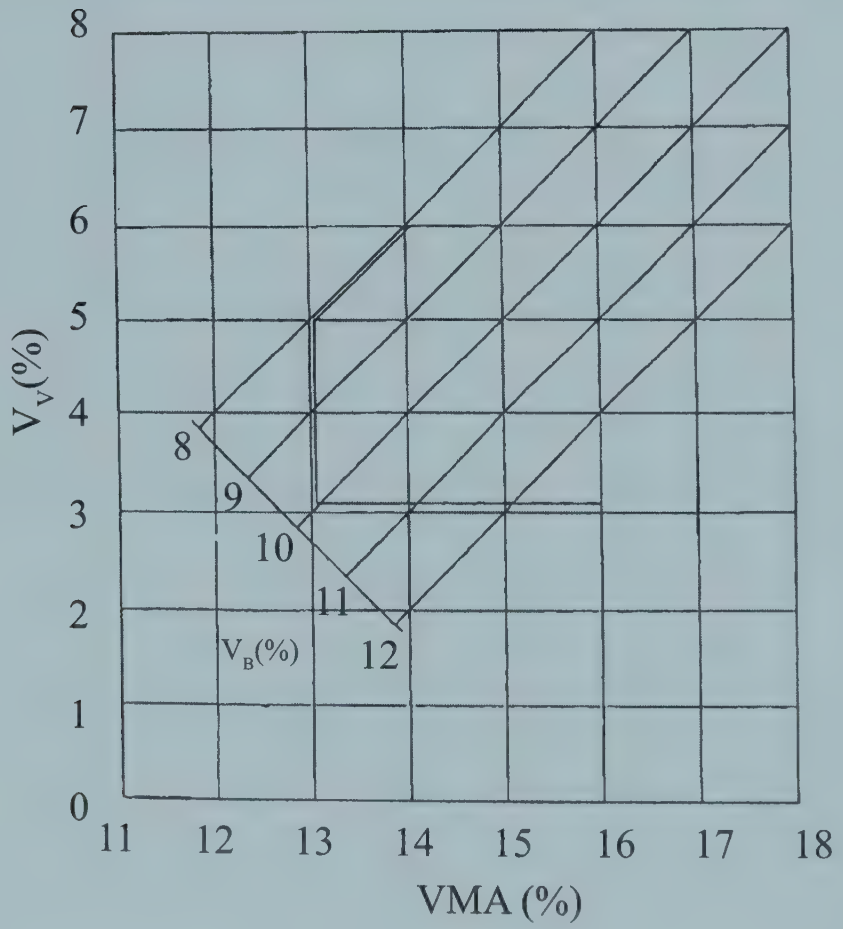


Fig. A 9.3. Volumetric Criteria Chart (3 per cent Voids at 100 PRD)

PROCEDURES FOR DETERMINING MECHANICAL PROPERTIES (STIFFNESS AND DEFORMATION RESISTANCE) OF BITUMINOUS MIXTURES

1. Determination of the Indirect Tensile Stiffness Modulus of Bituminous Mixtures

This test describes a method for measuring the indirect tensile stiffness modulus (ITSM) of bituminous mixtures. The method is applicable to cylindrical test specimens having a thickness between 30 mm and 80 mm, and a diameter between 100 mm and 200 mm.

The test should be carried out in accordance with the procedure described in BS:DD 213:1993.

2. Assessment of Resistance to Permanent Deformation of Bitumen Aggregate Mixtures Subject to Unconfined Uniaxial Loading

2.1. Scope

This test describes a method for determining the resistance to permanent deformation of bituminous mixtures at temperatures and loads similar to those experienced by these materials in roads. The methods are applicable to samples of wearing course, base-course and road-base.

The method can be used to rank bituminous mixtures on the basis of resistance to permanent deformation, as a guide to relative performance in the pavement and to obtain data for estimating potential deformation in the vehicle wheel-paths.

2.2. Method

The test should be carried out in accordance with the procedure described. in BS:DD 226:1996.

References

[1] British Standards Institution, "Method for determination of the indirect tensile stiffness modulus of bituminous mixtures", British Standard Draft for Development BS:DD 213, 1993.

[2] British Standards Institution, "Method for the assessment of resistance to permanent deformation or bitumen aggregate mixtures subject to unconfined uniaxial loading", British Standard Draft for DeVelopment BS:DD 226, 1996.

Appendix-11

PROCEDURE FOR INDIRECT TENSILE (SPLITTING) TEST

This test is very similar to the Indirect Tensile Fatigue Test except that, instead of applying repeated load on a specimen, the load is applied via a hydraulic ram which travels at a fixed velocity. This speed was chosen so as to allow a standard Marshall frame, with minor adjustments, to be used as the test apparatus. The test temperature chosen, 4°C, is selected since low temperature stressing is considered most critical. It effectively represents a weighted value.

The load cell of the Marshall frame is connected, via an analogue to digital converter, to a personal computer and continuous reading of the load cell is carried out. The piece of apparatus is very portable and can, therefore, be placed in any temperature control room, thus allowing low temperature work to be carried out. A schematic diagram of the system is shown in Fig. A 11.1.

Results

The data which can be assimilated from the test are shown in Fig. A 11.2.

The area under the load/time graph is calculated using Simpson's rule. This value, expressed in kNs, can be thought of as the energy dissipated during the test. A direct comparison of this value for energy disspipation can be made for different materials and hence, a ranking made.

The indirect tensile strength can also be determined, as described in ASTM D4867(1).

Reference

[1] American Society for Testing and Materials, "Standard test method for effect of moisture on aspalt concrete paving mixtures", American Society for Testing and Materials ASTM Designation D4867, 1992.

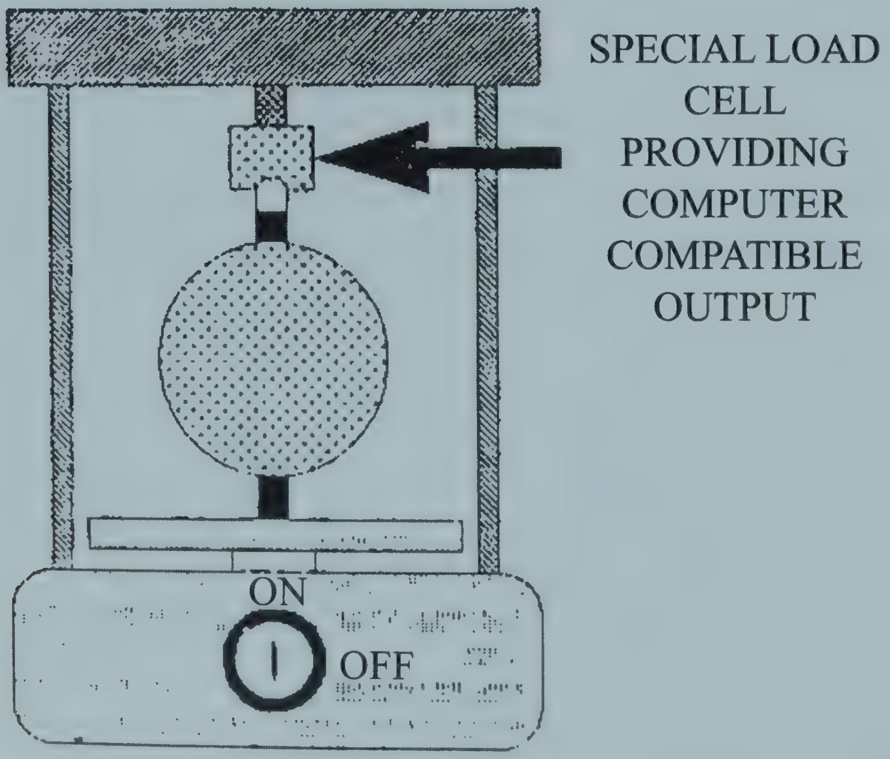
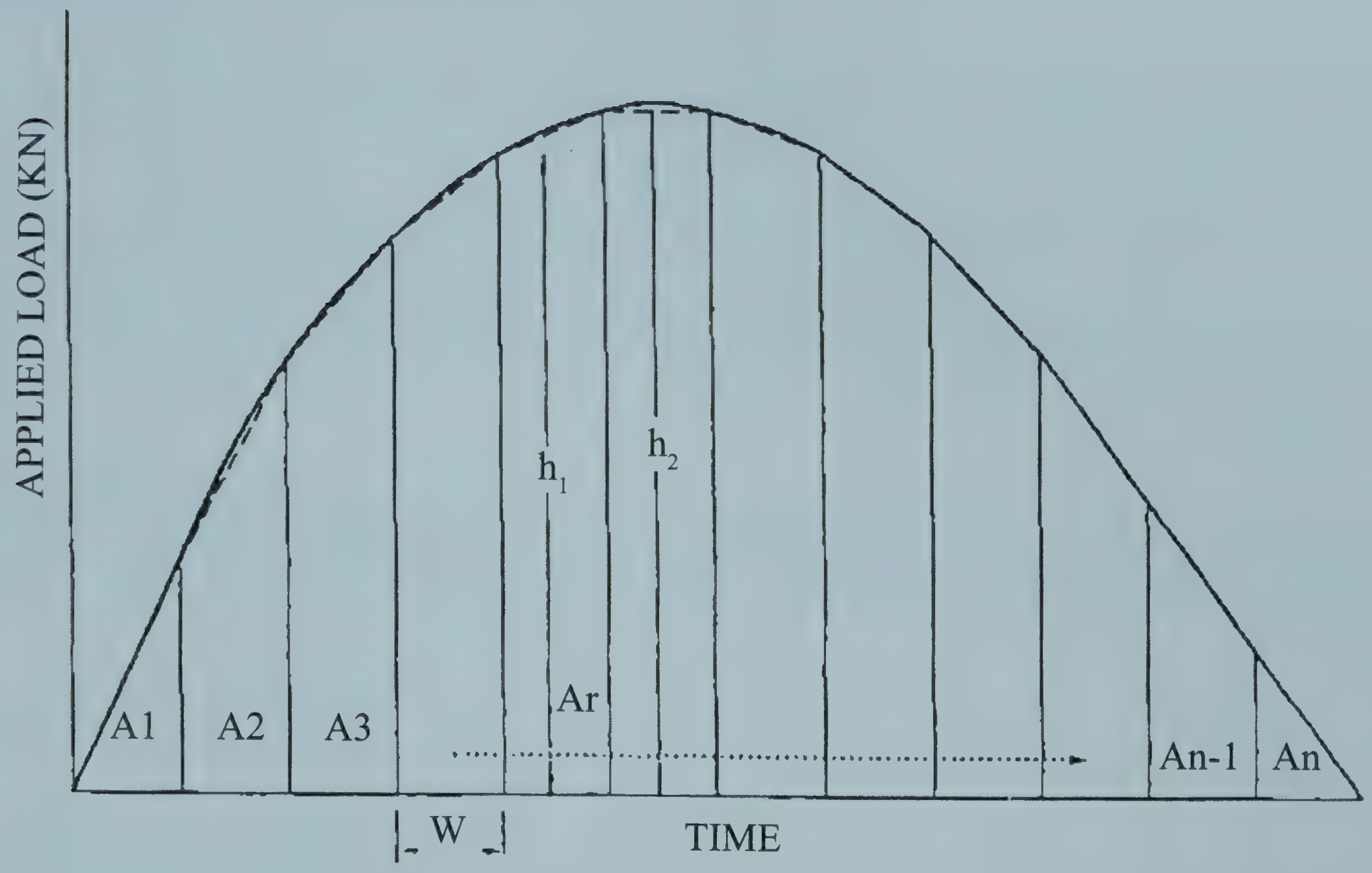


Fig. A 11.1. Schematic Diagram of ITST


APPLIED LOAD (KN)
h_1
h_2
A1
A2
A3
Ar
An-1
An
W
TIME

$$Ar = \frac{(h_1 + h_2)}{2} \times w \ : \ \text{Total Area} = \sum_{r=1}^{n} Ar$$

Fig. A 11.2. Typical Output from the ITST

PROCEDURE FOR LONG TERM OVEN AGEING AND FATIGUE TESTING OF BITUMINOUS MIXTURES

1. Standard Practice for Long-Term Oven Ageing of Compacted Bituminous Mixtures

1.1. Scope

This standard practice is used to simulate the long-term ageing of compacted bituminous mixtures. Long-term ageing considers the hardening of the bitumen in the mixture subsequent to construction. The practice should result in ageing representative of 5 to 10 years in service for dense-graded mixtures.

1.2. Definitions

1.2.1. Ageing

Ageing refers to the hardening or embrittlement of the bitumen in bitumen-aggregate mixtures as a result of compositional changes in the bitumen due to many factors such as time, temperature, oxidation, steric hardening, ultraviolet radiation, etc.

1.2.2. Long term ageing

Long-term ageing refers to the hardening or embrittlement of the bitumen in bitumen-aggregate mixtures subsequent to construction of the pavement layer incorporating the bituminous mixture.

1.3. Apparatus

1.3.1. Oven

Oven: forced-draft oven which is thermostatically controlled and capable of being set to maintain any desired temperature from room temperature to 260°C with an accuracy of ± 1°C or less.

1.3.2. Digital thermometer

Digital thermometer capable of measuring temperatures from room temperature to 260°C and having an accuracy of ± 1°C or less.

1.3.3.

Wire mesh, of sufficient rigidity to support the compacted specimens without bending or flexing appreciably, having an open area to total area ratio of at least 75 per cent. Steel Expamet has been found to be suitable for this purpose.

1.4. Sampling

Plant-mixed materials should be sampled in accordance with BS:598: Part 100: 1987.

1.5. Preparation

1.5.1. Laboratory-prepared mixtures should be fabricated in accordance with the Standard Practice for Laboratory Preparation of Compacted Bituminous Mixtures or other suitable method such as BS:598 : Part 107 : 1990.

1.5:2. Plant-mixed materials should be heated to a temperature (±2°C) which corresponds to a kinematic viscosity of 3 Poise (0.3 Pas.) for the bitumen in the mixture and compacted in accordance with the Standard Practice for Laboratory Preparation of Compacted Bituminous Mixtures or other suitable method such as BS:598 : Part 107 : 1990.

1.6. Procedure

1.6.1. Place the specimen on the wire mesh in the forced-draft oven for 120 ± 0.25 hours at a temperature of 85 ± 1°C.

1.6.2. After 120 hours, turn off the oven, open the door and allow the specimen to cool to room temperature (24 hours should be a sufficient cooling period).

Note: Do not touch or remove the specimen until it has cooled to room temperature.

1.6.3. After the specimen has cooled to room temperature, remove it from the oven. The specimen is now ready for testing as required.

2. Method for the Determination of the Fatigue Characteristics of a Bituminous Mixture using the Indirect Tensile Fatigue Test

2.1. Scope

This test describes a method to estimate the resistance to fatigue failure of bituminous mixtures. The method is applicable to wearing courses, base courses and roadbases containing penetration grade bitumens or modified binders.

The results should only be considered as indicating the fatigue characteristics of bituminous mixtures, caution should be exercised when quoting finite values or when comparing results of different materials tested under different conditions or tested by different methods.

2.2. Method

The test should be carried out in accordance with the procedure described in BS DD ABF, 1995.

References

(1) Brown, S.F., Gibb, J.M., Read, J.M. Scholz, T.V., and Cooper, K.E., "Design and testing of bituminous mixtures", Report submitted to DOT/EPSRC LINK Programme on Transport Infrastructure and Operations, January 1995.

(2) British Standard Institution, "Method for the determination of the fatigue characteristics of bituminous mixtures using indirect tensile fatigue", Draft for Development DD ABF, 26 June 1995.

MODIFIED BINDER STORAGE STABILITY TEST

1. Scope

This test determines the susceptibility of a pre-blended modified binder to separation or instability during prolonged storage at high temperature.

2. Summary of Method

A sample of modified binder should be contained in a closed vessel of specific dimensions and should be maintained at 160 ± 2°C for 7 days ± 2 hours. A binder sample should then be taken from the top and bottom thirds of the vessel and both samples should be tested for compliance with the binder specification.

3. Apparatus

The apparatus should consist of:

(i) Cylinder, made of heat. resistant glass, 190 ± 130 mm long and 65 ± 5 mm internal diameter having a removable lid, flush fitting to exclude air when the cylinder is filled with binder, and provided with three drain-cocks, one at the base, the other two spaced equally down the side of the cylinder, to allow the sample to be divided into three equal portions as in paragraph 4 (vii) of the procedure.

Alternatively, a thin-wall' sheet metal tube or similar vessel such as a 500 ml beverage can, of similar dimensions to the glass cylinder, and having a similarly removable lid, fitted either with or without drain-cocks.

(ii) Oven, electrically heated, fan assisted, and capable of maintaining a temperature of 160 ± 2°C, having interior dimensions not less than 330 mm from the top of the heating element to the top of the chamber and not less than 305 mm in width and depth.

(iii) Tube holder, made of metal, that will hold either the glass cylinder or sheet metal can, in a vertical position, such that the base of the cylinder or can is not in direct contact with the oven floor.

(iv) Apparatus for determining the penetration and softening point of bitumen in accordance with IS:1203 and IS:1205.

(v) Transfer dishes (3), made of metal, each of a capacity sufficient to hold at least one third of the test sample.

4. Test Procedure

The procedure should be as follows:

(i) The bulk sample of modified binder should be obtained by a representative sampling method.

(ii) Place the bulk sample of modified binder and the glass cylinder (or metal tube or equivalent vessel) in the preheated oven at 160 ± 2°C for a period not exceeding 3.75 ± 0.25 hours.

(iii) Remove the bulk sample from the oven and thoroughly mix by stirring to ensure obtaining a representative test sample.

(iv) Remove the glass cylinder (or metal tube or equivalent vessel) from the oven and completely fill with the modified binder test sample to allow no air space when the lid is fitted.

(v) Support the filled cylinder in a vertical position in the holder and transfer to the oven which should be controlled at a temperature of 160 ± 2°C apd allow to stand undisturbed for a period of 168 ± 2 hours.

(vi) If a vessel having drain-cocks has been used for the test proceed using Method A below, otherwise proceed using Method B.

(vii) Method A

(a) Remove the glass cylinder (or alternative approved vessel) from the oven, keeping the cylinder vertical.

(b) Open the upper-most drain-cock and run off the top third portion of the test sample into a transfer dish for testing.

(c) Open the middle drain-cock and run off the middle third portion of the test sample into a suitable container and discard.

(d) Open the lower drain-cock and run off the middle third portion of the test sample into a transfer dish for testing.

(viii) Method B

(a) Remove the tube or vessel containing the test sample from the oven and allow it to cool at room temperature for 2 ± 0.25 hours whilst maintaining the vessel vertical in the holder.

(b) When the vessel of modified binder has cooled to ambient temperature, remove it from the tube holder and make two cuts through the vessel and the sample at positions one-third and two-thirds of the length from, and parallel, to the base.

(c) Retain the top and bottom thirds of the test samples for further testing and discard the middle third.

(ix) Determine the penetrations and softening points of the top and bottom thirds of the test sample, in accordance with IS:1203 and IS:1205.

5. Reporting

For both the top and bottom thirds of the test sample the following should be reported:

(i) The penetration, in accordance with the requirements of IS:1203.

(ii) The softening point, in accordance with the requirements of IS:1205

(iii) Whether Method A or Method B was used.

(iv) The location and date of obtaining the bulk sample, and the dates of test.

PROTECTION OF THE ENVIRONMENT

1. General

1.1. This Appendix sets out limitations orl the Contractor's activities specifically intended to protect the environment.

1.2. The Contractor should take all necessary measures and precautions and otherwise ensure that the execution. of the works and all associated operations on site or off-site are carried out in conformity with statutory and regulatory environmental requirements including those prescribed elsewhere in this document.

1.3. The Contractor should take all measures and precautions to avoid any nuisance or disturbance arising from the execution of the Works. This should wherever possible be achieved by suppression of'the nuisance at source rather than abatement of the nuisance once generated.

1.4. In the event of any spoil, debris, waste or any deleterious substance from the Site being deposited on any adjacent land, the Contractor should immediately remove all such material and restore the effected area to its original state to the satisfaction of the Engineer.

2. Water Quality

2.1. The Contractor should prevent any interference with the supply to or abstraction from, and prevent any pollution of, water resources (including underground percolating water) as a result of the execution of the Works.

2.2. Areas where water is regularly or repetitively used for dust suppression purposes should be laid to fall to specially-constructed settlement tanks to permit sedimentation of particulate matter. After settlement, the water may be re-used for dust suppression and rinsing.

2.3. All water and other liquid waste products arising on the Site should be collected and disposed of at a location on or off the Site and in a manner that should not cause either nuisance or pollution.

2.4. The Contractor should not discharge or deposit any matter arising from the execution of the Works into any waters except with permission from the regulatory authorities concerned.

2.5. The Contractor should at all times ensure that all existing stream courses and drains within, and adjacent to, the Site are kept safe and free from any debris and any materials arising from the Works.

2.6. The Contractor should protect all watercourses, waterways, ditches, canals, drains, lakes and the like from pollution as a result of the execution of the Works.

3. Air Quality

3.1. The Contractor should devise and arrange methods of working to minimise dust, gaseous or other airborne emissions and carry out the Works in such a manner as to minimise adverse impacts on air quality.

3.2. The Contractor should utilise effective water sprays during delivery manufacture, processing and handling of materials when dust is likely to be created, and to dampen stored materials during dry and windy weather. Stockpiles of friable materials should be covered with clean tarpaulins, with application of sprayed water during dry and windy weather. Stockpiles of material or debris should be dampened prior to, their movement, except where this is contrary to the Specification.

3.3. Any vehicle with an open load-carrying area used for transporting potentially dust producing material should have properly fitting side and tail boards. Materials having the potential to produce dust should not be loaded to a level higher than the side and tail boards, and should be covered with a clean tarpaulin in good condition. The tarpaulin should be properly secured and extend at least 300 mm over the edges of the side and tail boards.

3.4. In the event that the Contractor is permitted to use gravel or earth roads for haulage, he should provide suitable measures for dust palliation, if these are considered necessary. Such measures may include spraying the road surface with water at regular intervals.

4. Noise

4.1. The Contractor should consider noise as an environmental constraint in his planning and execution of the Works.

4.2. The Contractor should take all necessary measures so that the operation of all mechanical equipment and construction processes on and off the Site should not cause any unnecessary or excessive noise, taking into account applicable environment requirements. The Contractor should use all necessary measures and should maintain all plant and silencing equipment in good condition so as to minimise the noise emission during construction works.

5. Control of Wastes

5.1. The Contractor should control the disposal of all forms of waste generated by the construction operations and in all associated activities. No uncontrolled deposition or dumping should be permitted. Wastes to be so controlled should include, but should not be limited to, all forms of fuel and engine oils, all types of bitumen, cement, surplus aggregates, gravels, bituminous mixtures etc. The Contractor should make specific provision for the proper disposal of these and any other waste products, conforming to local regulations and acceptable to the Engineer.

6. Emergency Response

6.1 The Contractor should plan and provide for remedial measures to be implemented in the event of occurrence of emergencies such as spillages of oil or bitumen or chemicals.

6.2. The Contractor should provide the Engineer with a statement of the measures he intends to implement in the event of such an emergency which should include a statement of how he intends to provide personnel adequately trained to implement such measures. This statement should accompany the programme to be submitted by the Contractor in accordance with the provision of the Conditions of Contract.

EQUIPMENT FOR FIELD LABORATORY (TO TEST MATERIALS FOR BITUMINOUS LAYERS)

(A) For Testing of Aggregates

(a) Particle Size Distribution as per IS:2386 Part I with standard set of sieves, lid and pan 450 mm diameter for coarse aggregate:

63 mm, 53 mm, 37.5 mm, 26.5 mm, 13.2 mm, 9.5 mm, 6.7 mm, and 4.75 mm size

200 mm diameter for fine aggregate:

2.36 mm, 2.0 mm, 1.18 mm, 600 micron, 425 micron, 300 micron, 150 micron and 75 micron

Sieve shakers for both large and small diameter sieves.

(b) Flakiness and Elongation Test Gauges as per IS:2386 Part I.

(c) Riffle Boxes for'sampling of coarse and fine aggregates.

(d) Specific Gravity determination test apparatus with pycnometer/specific gravity bottles, vacuum pump.

(e) Standard moulds of 30, 15 and 3 litre capacity along with standard tamping rod.

(f) Aggregate Soundness Test apparatus as per IS:2386 Part 4.

(g) Los Angeles Abrasion Value Test apparatus as per IS:2386 Part 4.

(h) Water Absorption Test apparatus as per IS:2386 Part 5

(i) Aggregate Impact Value Test apparatus as per IS:2386 Part 4.

(j) Water Sensitivity Test apparatus as per AASHTO T283.

(k) Sand Equivalent Value Test apparatus as per IS:2720 (Part 37)

(B) For Testing of Bitumen and Liquid Bitumens

(a) Penetration Test apparatus with standard needles as per IS:1203

(b) R & B Softening Point Test apparatus with ring, ball, thermometer etc. as per IS:1205

(c) Flash Point: Cleveland Open Cup Test apparatus as per IS:1208

(d) Apparatus for determining Solubility in Trichloroethylene Test

(e) Float Test apparatus

(f) Tag Open Cup Test apparatus

(g) Saybolt Furol Viscometeras per IS:3117

(h) Emulsion Settlement Test apparatus

(i) Emulsion Storage Stability Test apparatus

(C) For Testing of Bituminous Mixtures

(a) Complete Marshall Stability Test apparatus as per ASTM D1559, electrically operated loading unit, Flowmeter, Automatic compactor, Testing head Assembly, Proving Ring with Dial Gauge, Specimen moulds, Base plates, Compaciton hammers, Specimen extractor, Water bath and other accessories.

(b) Mechanical mixer of 0.02 cum capacity, electrically operated and fitted with heating jacket

(c) Electrically operated Centrifuge type bitumen extractor and commercial benzene.

(d) Camber Board/Template and 3 m Straight Edge.

(e) Core cutting machine.

(f) Nuclear density gauge.

(D) General Equipment

(a) Ovens, electrically operated and thermostatically controlled up to 200°C and 300°C (sensitivity 1°C)

(b) Balances complete with Weight Boxes: Platform type 300 kg capacity.

Beam type balance-20 kg capacity — 1 gm accuracy.

Chemical Balance 100 gm capacity 0.001 gm accuracy.

Physical Balance 250 gm capacity 0.01 gm accuracy.

Electronic Balance 5 kg capacity 0.01 gm accuracy

Self Indicating Type 7 kg and 10 kg capacities.

(c) Proving Rings (250 kg, 2000 kg capacities) and dial gauges (25 mm and 50 mm travel, 0.01 mm/division)

(d) Hot Plate, electrically operated and kerosene or gas stoves.

(e) Electrically operated and thermostatically controlled water bath.

(f) Thermometers:

Metallic Type (Mercury in steel) with 30 cm stem and 3 m stem for near and distant readings.

Glass Type (Mercury-in-glass) ranges of 110°C, 250°C, 400°C

(g) Glassware, flasks, graduated cylinders, spatulas wire gauges, scoops, steel scales, measuring tapes, casserols, assorted sizes of enameled trays, filter paper glass marking pencils, heat resistant hand gloves, vernier callipers etc.

(h) First Aid Box.

EQUIPMENT FOR CENTRAL LABORATORY (TO TEST MATERIALS FOR BITUMINOUS LAYERS)

(A) For Testing of Aggregates

(a) Particle Size Distribution as per IS:2386 Part I with standard set of sieves, lid and pan 450 mm diameter for coarse aggregate:

63 mm, 53 mm, 37.5 mm, 26.5 mm, 13.2 mm, 9.5 mm, 6.7 mm, and 4.75 mm size

200 mm diameter for fine aggregates:

2.36 mm, 2.0 mm, 1.18 mm, 600 micron, 425 micron, 300 micron, 150 micron and 75 micron

Sieve shakers for both large and small diameter sieves

(b) Flakiness and Elongation Test Gauges as per IS:2386 Part I.

(c) Riffle Boxes for sampling of coarse and fine aggregates.

(d) Specific Gravity determination test apparatus with pycnometer/specific gravity bottles, vacuum pump.

(e) Standard moulds of 30, 15 and 3 litres capacity along with standard tamping rod.

(f) Aggregate Soundness Test apparatus as per IS:2386 Part 4.

(g) Water Absorption Test apparatus as per IS:2386 Part 5

(h) Los Angeles Abrasion Value Test apparatus as per IS:2386 Part 4.

(i) Aggregate Impact Value Test apparatus as per IS:236 Part 4.

(j) Stripping Test apparatus as per IS:6241

(k) Polished Stone Value Test apparatus as per BS:812 Part 114.

(1) Sand Equivalent Value Test apparatus as per IS:2720 (Part 37)

(B) For Testing of Bitumen and Liquid Bitumens

(a) Penetration Test apparatus with standard needles as per IS:1203.

(b) R & B Softening Point Test apparatus with ring, ball, thermometer etc. as per IS:1205.

(c) Ductility Test apparatus at 27°C and at 15°C as per IS:1208

(d) Fraass Breaking Point Test apparatus as per 1S:9381

(e) Flash Point: Cleveland Open Cup Test apparatus as per IS:1208

(f) Viscosity Test apparatus: Capillary Viscometers and Standard Tar Viscometer as per Indian Standards IS:1208.

(g) Thin Film Oven Test apparatus.

(h) Rotating Thin Film Oven Test apparatus.

(i) Apparatus for determining Solubility is Trichloroethylene Test

(j) Elastic Recovery Test apparatus for Polymer Modified Bitumen as per Manufacturers' method.

(k) Polymer content test apparatus for Polymer Modified Bitumen as per Manufacturers' method.

(l) Float Test apparatus

(m) Tag Open Cup Test apparatus

(n) Distillation Test Apparatus for Cut-backs

(o) Saybolt Furol Viscometer as per IS:3117

(p) Emulsion Settlement Test apparatus

(q) Emulsion Storage Stability Test apparatus

(r) Emulsion Classification test apparatus.

(s) Emulsion Demulsibility Test apparatus.

(t) Cement Mixing Test apparatus.

(u) Particle Charge Test apparatus.

(v) Emulsion Sieve Test apparatus

(w) Distillation Test apparatus for emulsions.

(x) All laboratory equipment needed for developing Specifications for performance-based grades of bitumen.

(C) For Testing of Bituminous Mixtures

(a) Complete Marshall Stability Test apparatus as per ASTM D1559, electrically operated loading unit, Flowmeter, Automatic compactor, Testing head Assembly, Proving Ring with Dial Gauge, Specimen moulds, base plates, compaction hammers, specimen extractor, Water Bath and other accessories.

(b) Mechanical mixer of 0.02 cum capacity, electrically operated and fitted with heating jacket

(c) Electrically operated Centrifuge type bitumen extractor and commercial benzene.

(d) Camber Board/Template and 3 m Straight Edge.

(e) Apparatus for the Water Sensitivity Test as per AASHTO T283.

(f) Core cutting machine.

(g) Nuclear density gauge.

(h) All laboratory equipment needed for the Refused Density Design of High Performance Base and quality control during construction.

(D) General Equipment

(a) Ovens, electrically operated and thermostatically controlled up to 200°C and. 300°C (sensitivity 1°C)

(b) Balances complete with Weight Boxes: Platform type 300 kg capacity.

Beam type balance-20 kg capacity — 1 gm accuracy.

Chemical Balance 100 gm capacity 0.001 gm accuracy.

Physical Balance 250 gm capacity 0.01 gm accuracy.

Electronic Balance 5 kg capacity 0.01 gm accuracy

Self Indicating Type 7 kg and 10 kg capacities.

(c) Proving Rings (250 kg, 2000 kg 5000 kg capacities) and dial gauges (25 mm and 50 mm travel, 0.01 mm/division)

(d) Hot Plate, electrically operated and kerosene or gas stoves.

(e) Efectrically operated and thermostatically controlled water bath.

(f) Thermometers:

Metallic Type (Mercury in steel) with 30 cm stem and 3 m stem for near and distant readings.

Glass Type (Mercury-in-glass) ranges of 110°C, 250°C, 400°C

(g) Glasswares, flasks, graduated cylinders, spatulas, wire gauzes, scoops, steel scales, measuring tapes, casserols, assorted sizes of enamelled trays, Filter paper glass marking pencils, heat resistant hand gloves, vernier calipers etc.

(h) First Aid Box.